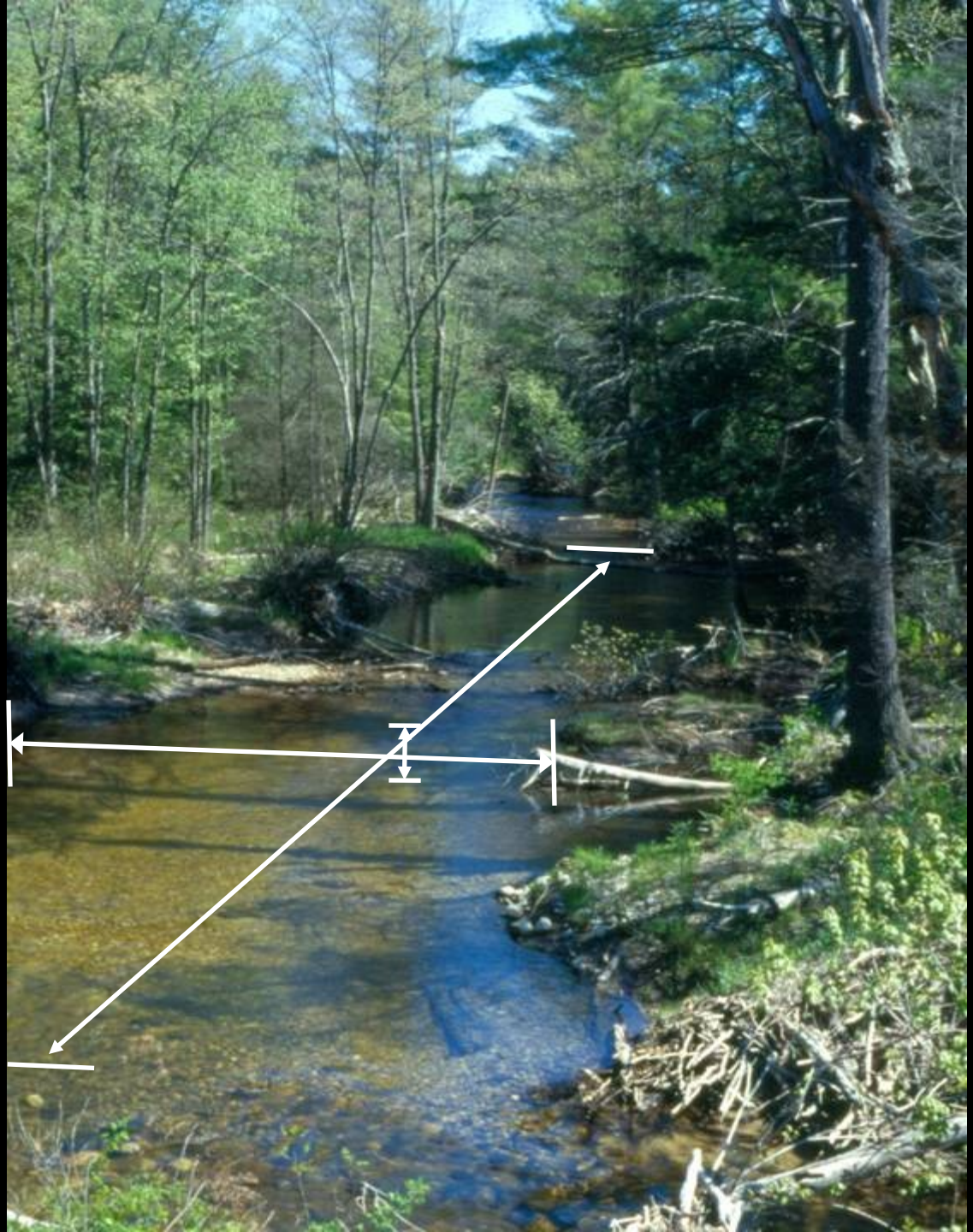
UMassAmherst Outreach UMass Extension

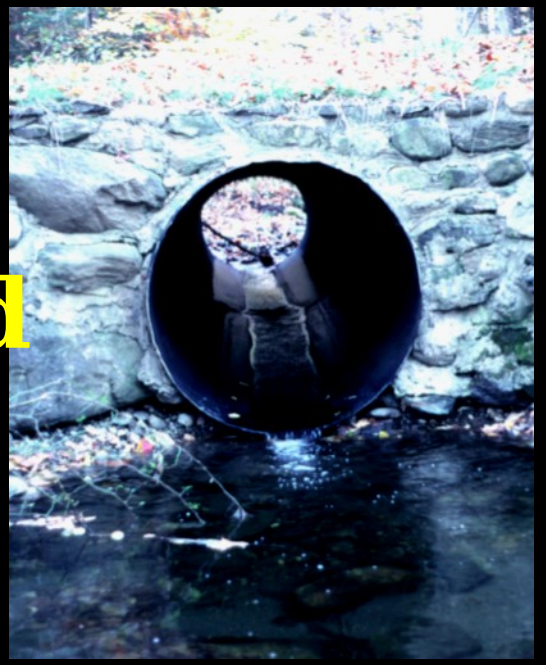
Protecting and Enhancing River & Stream Continuity

Scott Jackson
iversity of Massachusetts Amhe



Dams

Sub-standard Culverts



Micrographia

Scott Jackson

Scott Jackson

Radu Guiasu

Micrographia

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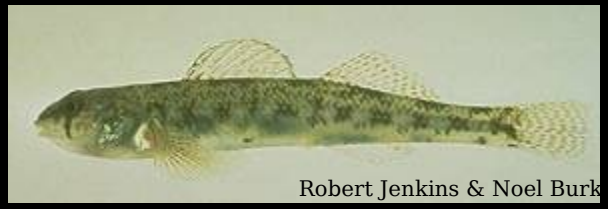

Robert Jenkins & Noel Burkhead

Barry Wicklow

Kenneth Catania

Importance of Movement

- Daily movements
- Changes in habitat conditions
- Reproduction
- Exploit vacant habitat
- Population continuity
- Dispersal

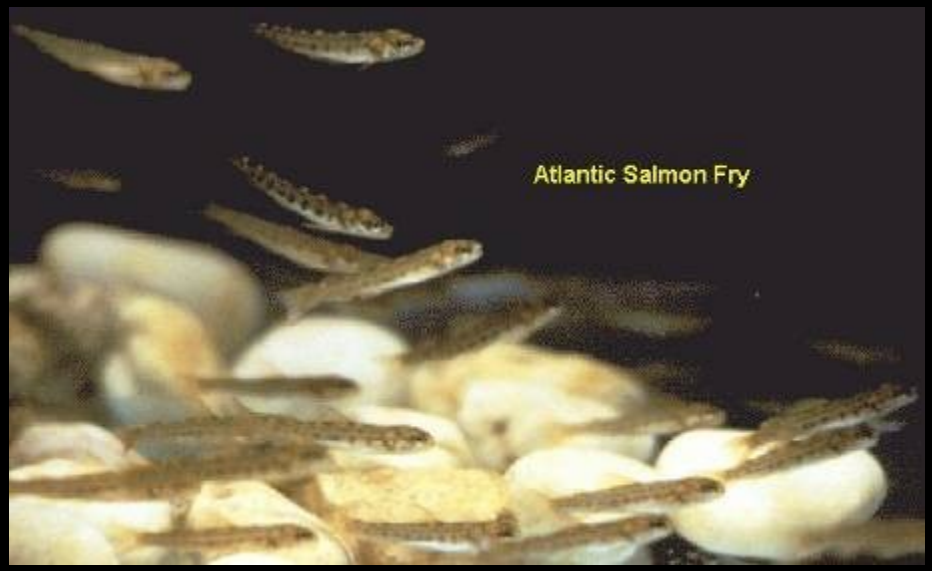
Adult Spawning Migrations

Spawning Habitat
Eggs & Alevin

Requirements:

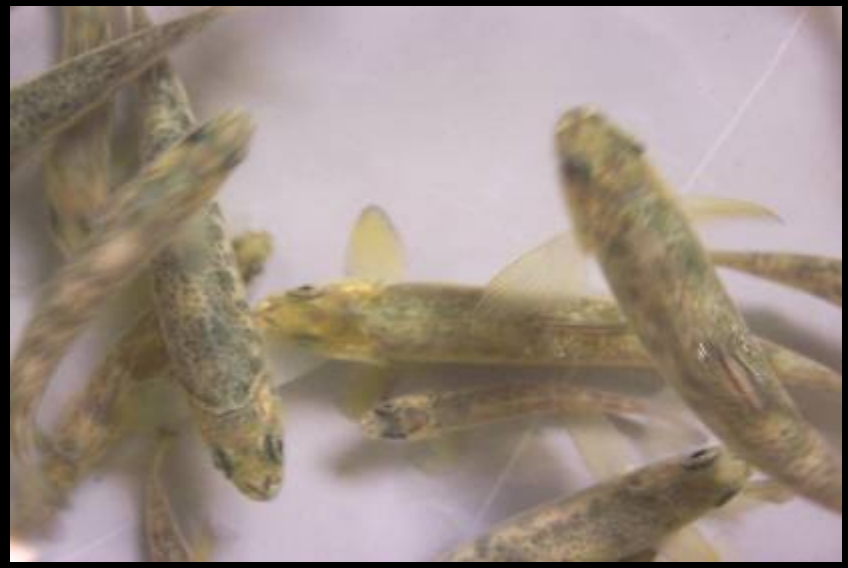
- **Clean, well oxygenated gravels**

Salmon Fry



Requirements:

- **Margin habitats with slow-moderate current**
- **Sufficient invertebrate prey**
- **Interstitial spaces**



Early Parr

Requirements:

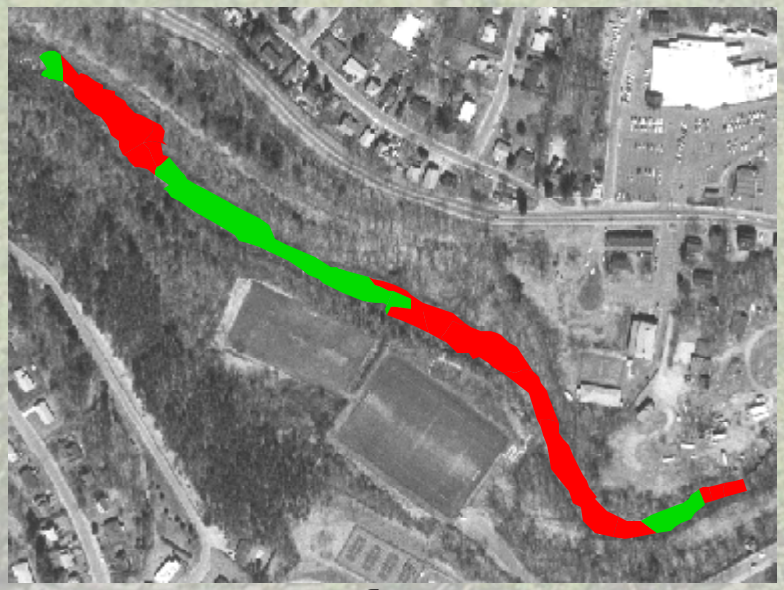
- Habitat with moderate-swift current
- Sufficient invertebrate prey
- Adequate interstitial spaces

Late Parr / Pre-smolt

Requirements:

- **Overwinter cover**
- **Require larger shelters**
- **Appropriate water chemistry**
- **Ability to emigrate from natal streams at certain times of the year**

At this stage salmon make extensive movements seeking appropriate winter habitat



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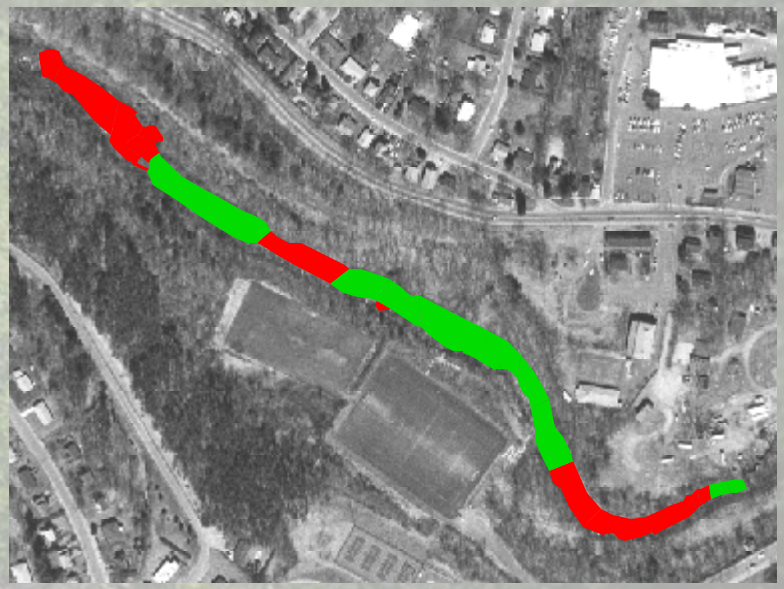

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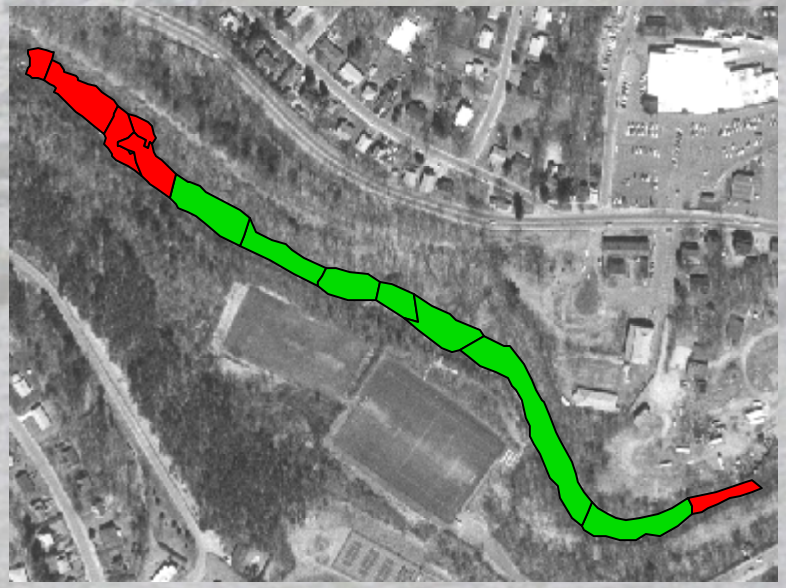
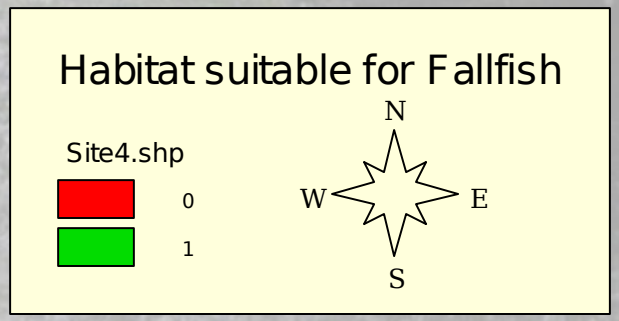




Piotr Parasiewicz

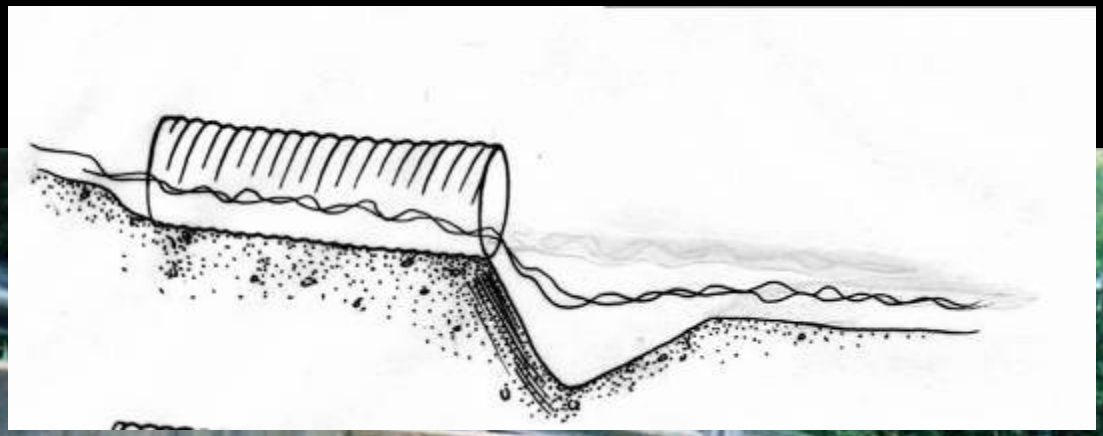
Excessive Velocities

Inlet Drop

Flow Contract

Kozmo Bates
Kozmo@AquaKoz.com

Scour Ho

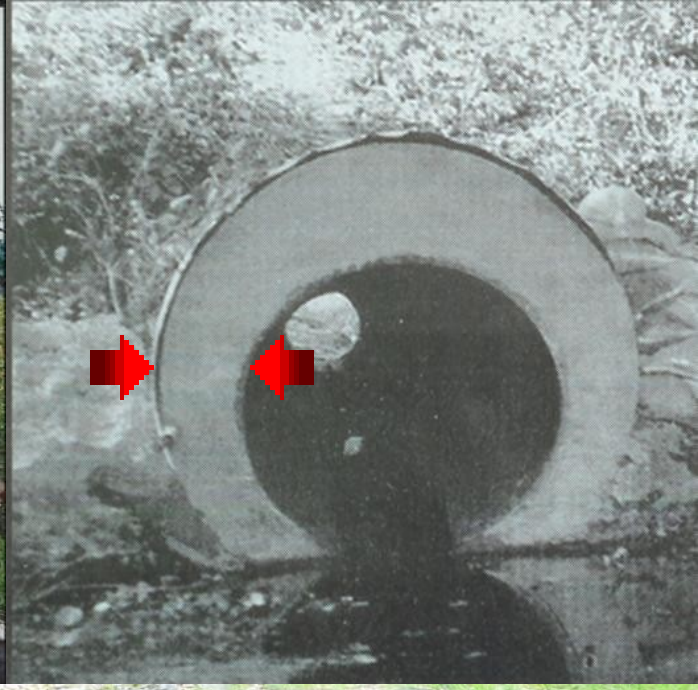


Outlet Drop (Perching)

Tail Water Armoring

Insufficient Wat
Depth

HDPE Slip liners vs. AOP



High Density Polyethylene (HDPE) & other pipes w/low-friction coefficient vs. Aquatic Organism Passage (AOP)

- Increase hydraulic capacity:
  - a 4” smaller pipe can pass 187% more flow (30” corrugated metal vs. 26” HDPE).
- Increase flow velocities: typically 2x
- Reduce water depths: 1/3 – 1/4
- Raise the culvert outlet: up to 8”
- Create channel scour
- HDPE don’t rust or corrode: considerable project longevity postpones correction when replacing.

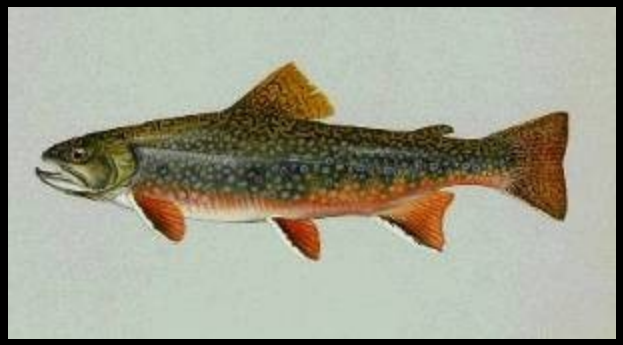
MATERIAL	Manning n
Natural Streams	
Sluggish with Deep Pools	0.040
Major Rivers	**0.035**
Clean and Straight	0.030
Floodplains	
Trees	0.150
Heavy Brush	0.075
Light Brush	0.050
Pasture, Farmland	0.035
Excavated Earth Channels	
Stony, Cobbles	0.035
Weedy	0.030
Gravelly	0.025
Clean	0.022

MATERIAL	Manning n
Metals	
Corrugated Metal	**0.022**
Cast Iron	0.013
Smooth Steel	0.012
Brass	0.011
Non-Metals	
Gravel	0.029
Masonry	0.025
Earth	0.025
Asphalt	0.016
Brickwork	0.015
Clay Tile	0.014
Unfinished Concrete	**0.014**
Unplaned Wood	0.013
Finished Concrete	0.012
Planed Wood	0.012
Glass	0.010

Corrugated Polyethylene (PE) with corrugated inner walls [c]	0.018-0.025
	0.009-

http://www.lmnoeng.com/manningn.htm

Micrographia



Alan Richmond

Micrographia

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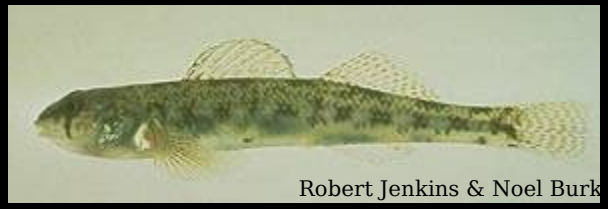
Barry Wicklow


Robert Jenkins & Noel Burk ad

Impacts of River & Stream Crossings

- Habitat loss and degradation
- Roadkill leading to loss of populations
- Alteration of Ecological Processes
- Reduced access to vital habitats
- Population fragmentation & isolation
- Disruption of processes that maintain regional populations

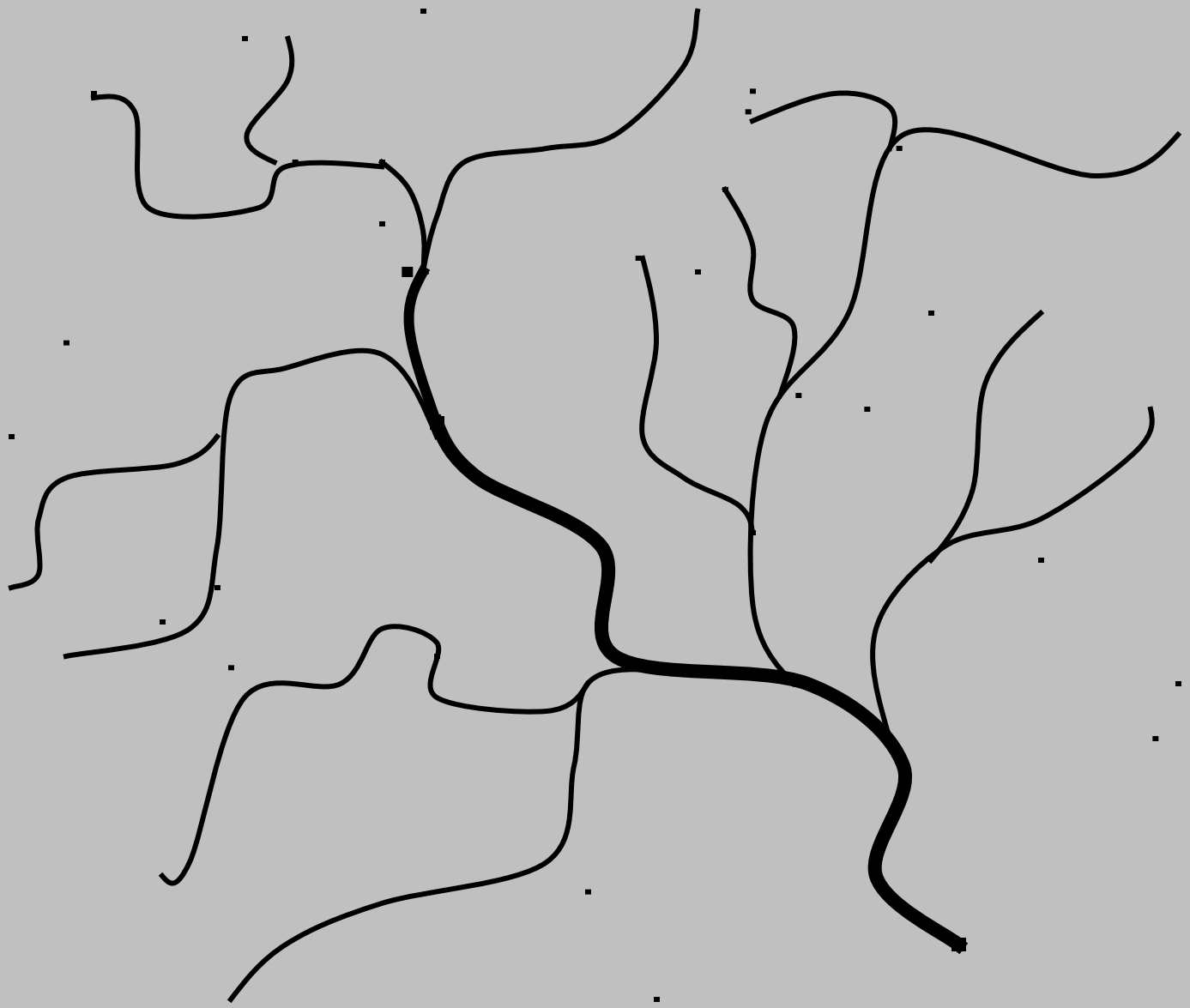
Culvert Failure

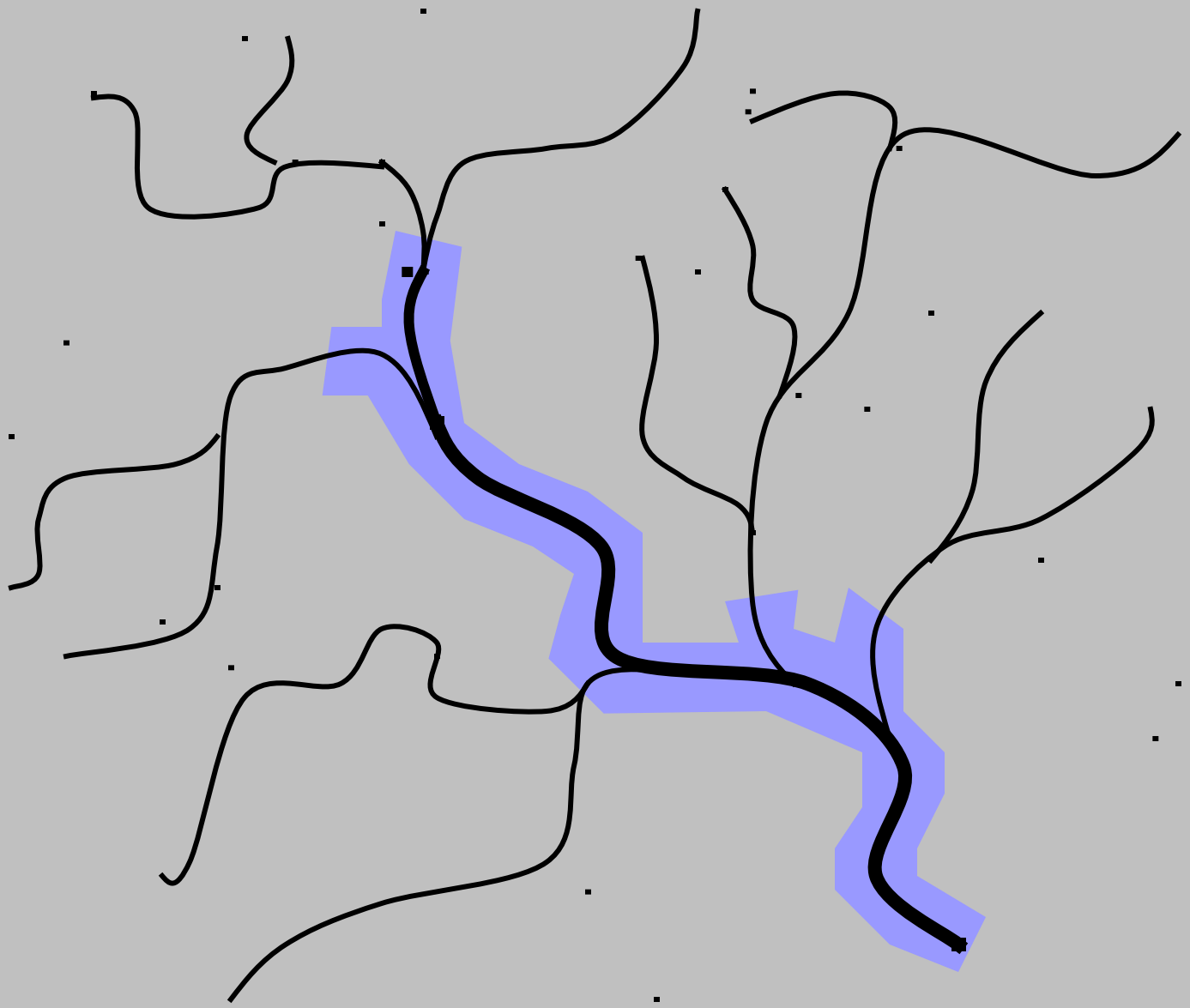
Impacts of River & Stream Crossings

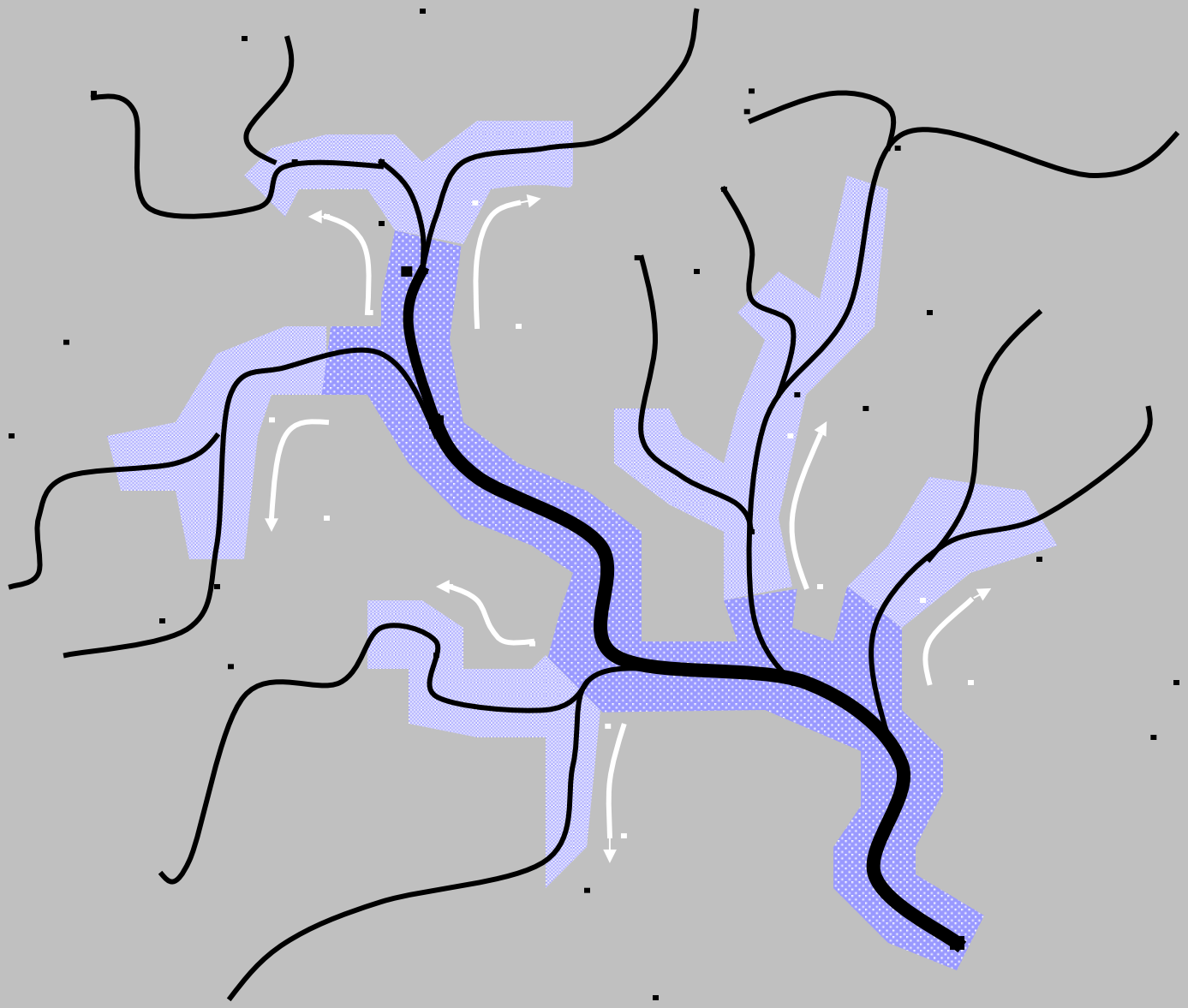
- **Blowouts cause hazard to life & property:**
  - **at the culvert and downstream**
  - **on perennial and intermittent streams**
  - **cause downstream structures to fail (cascading effect)**
  - **1.2 x bankfull + 2’ may avoid blowouts**

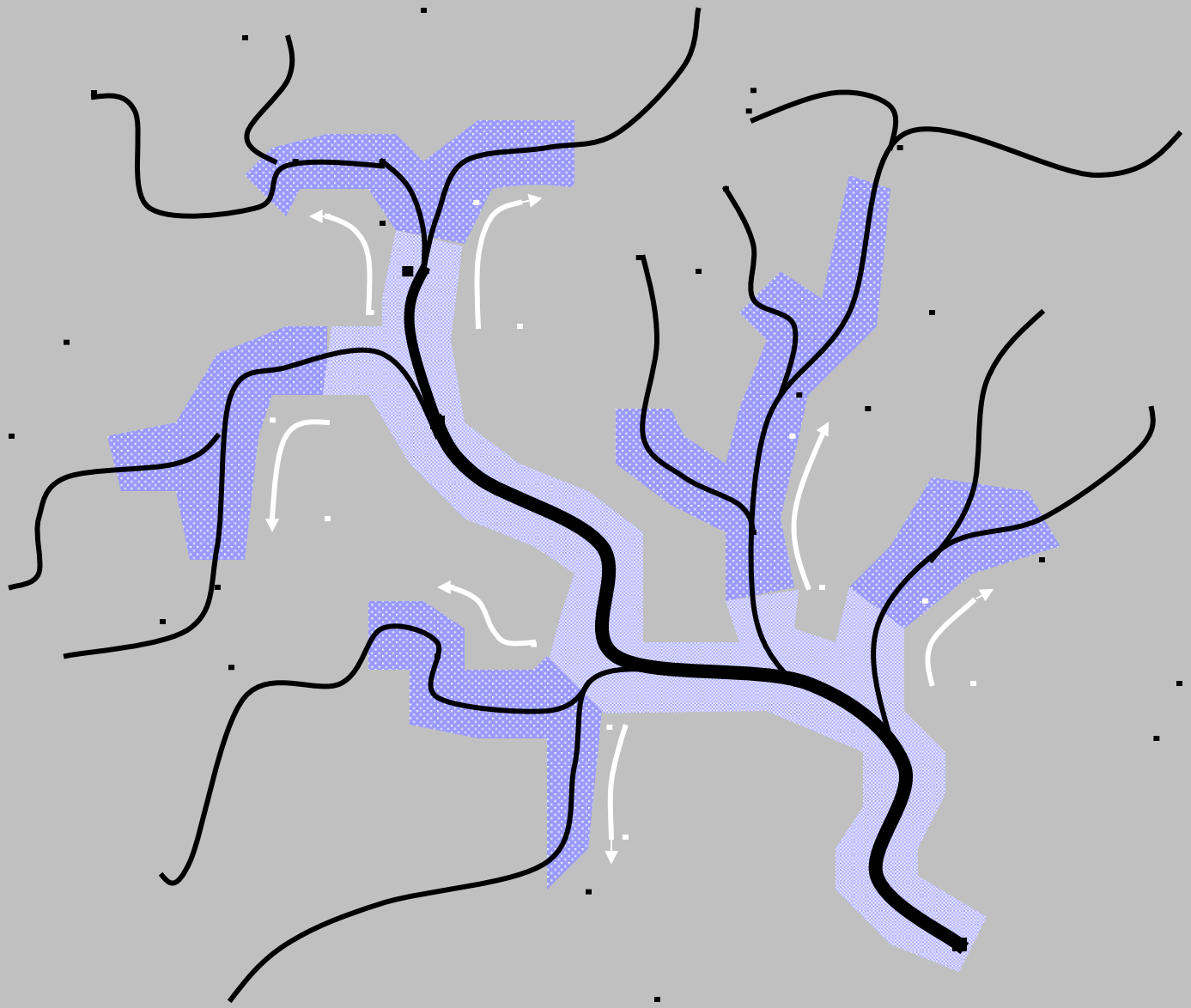
Reduced Access to Vital Habitats

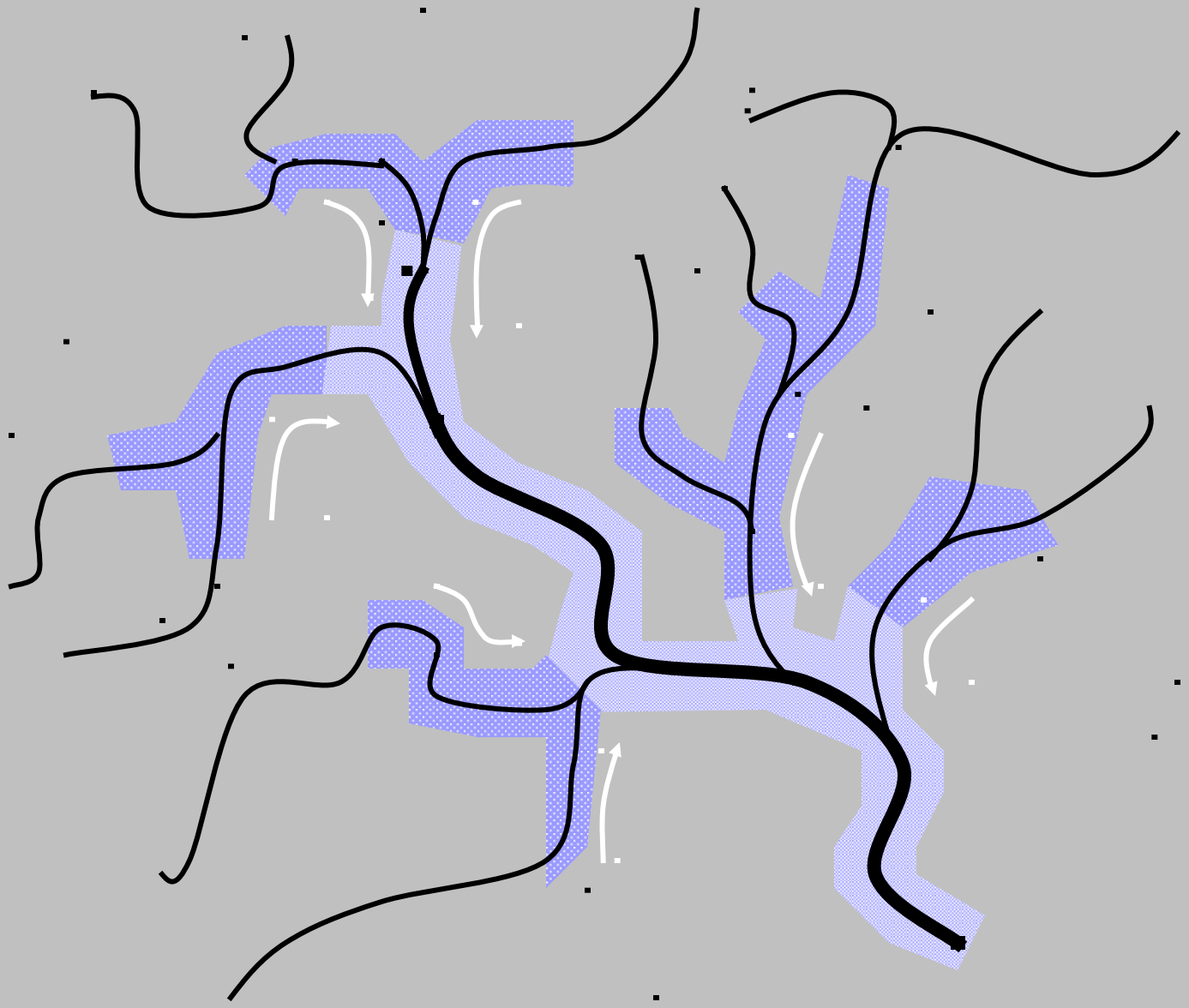
- Spawning habitat
- Nursery habitat
- Foraging areas
- Deep water refuges
- Seasonal habitats

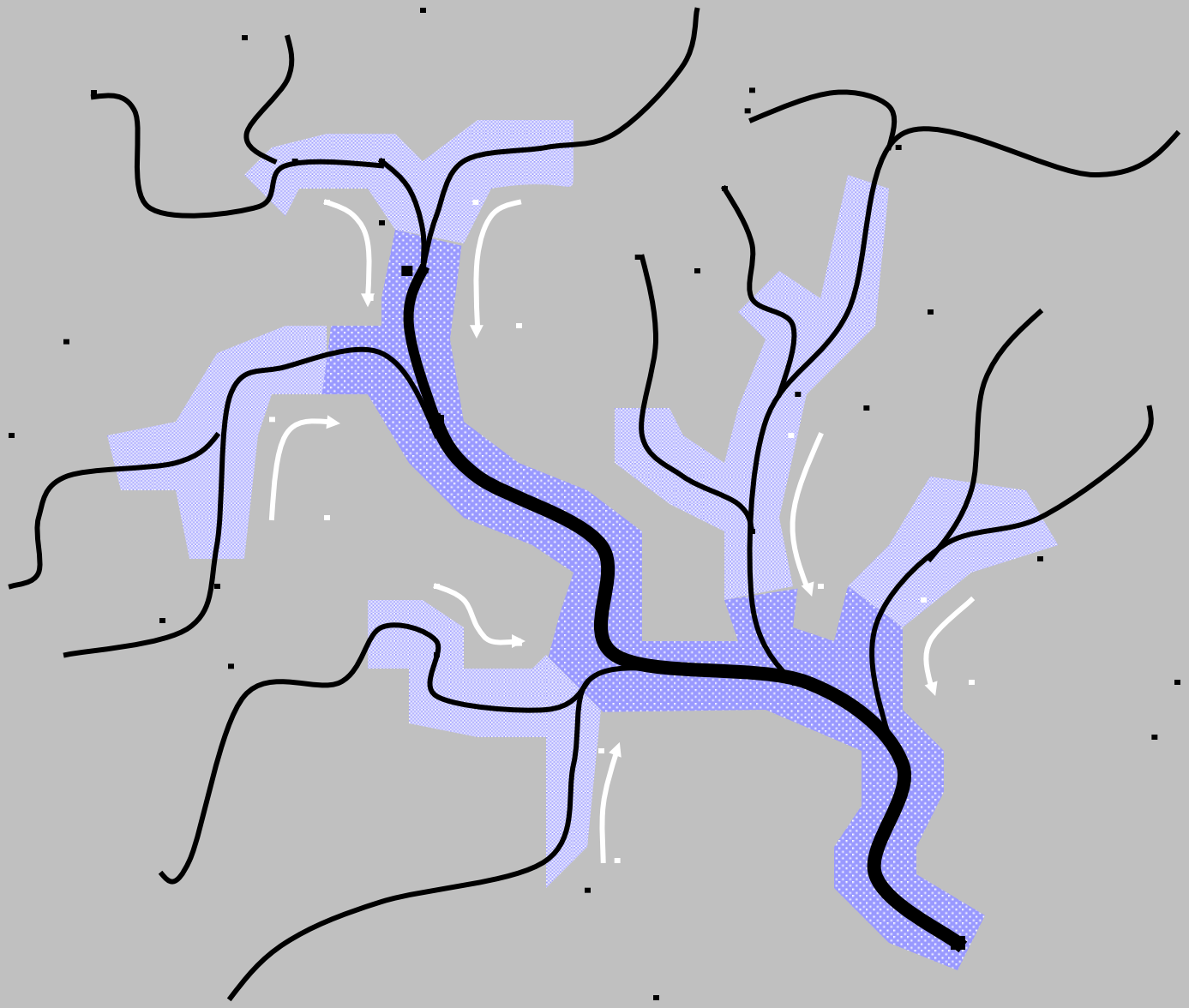


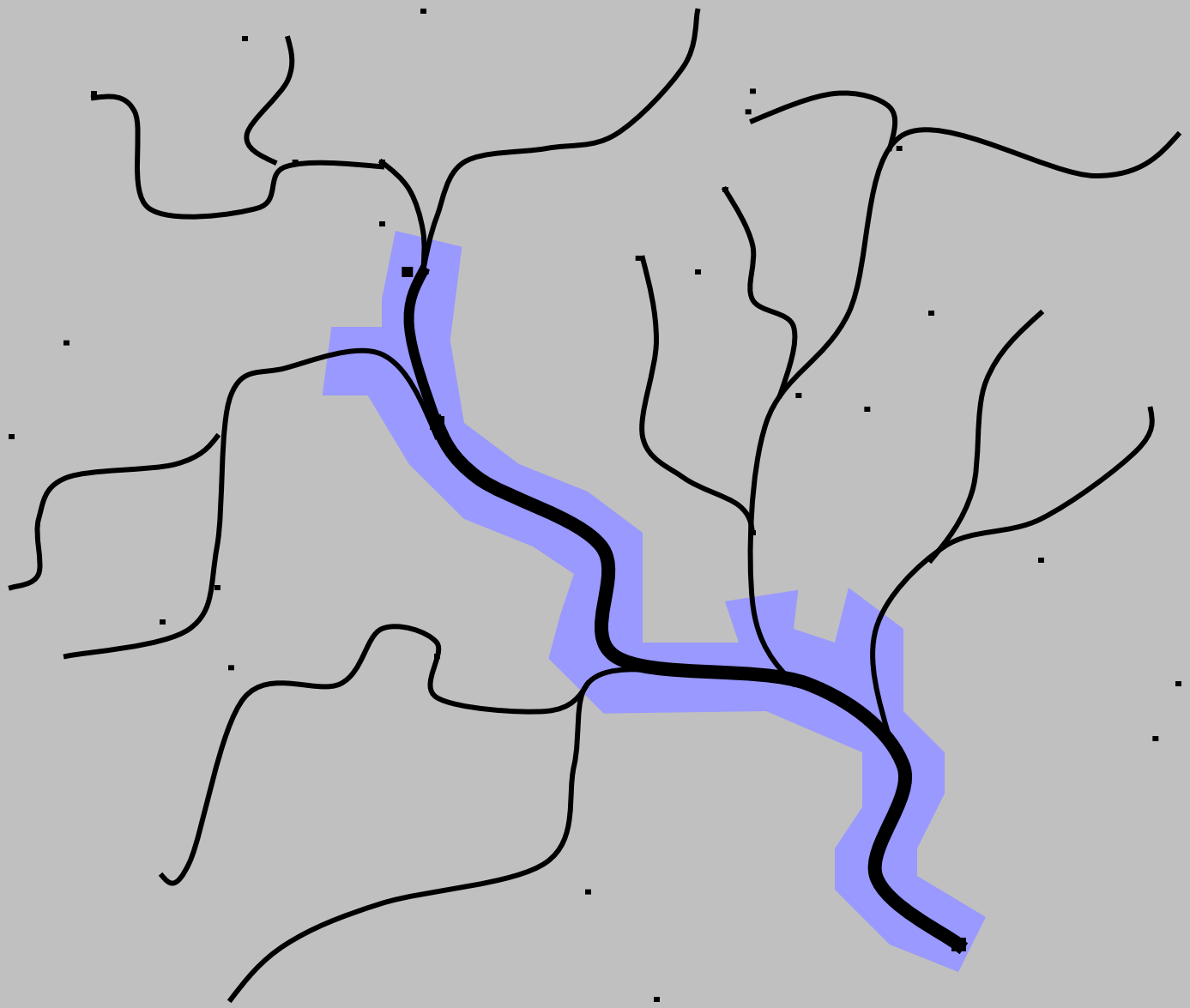


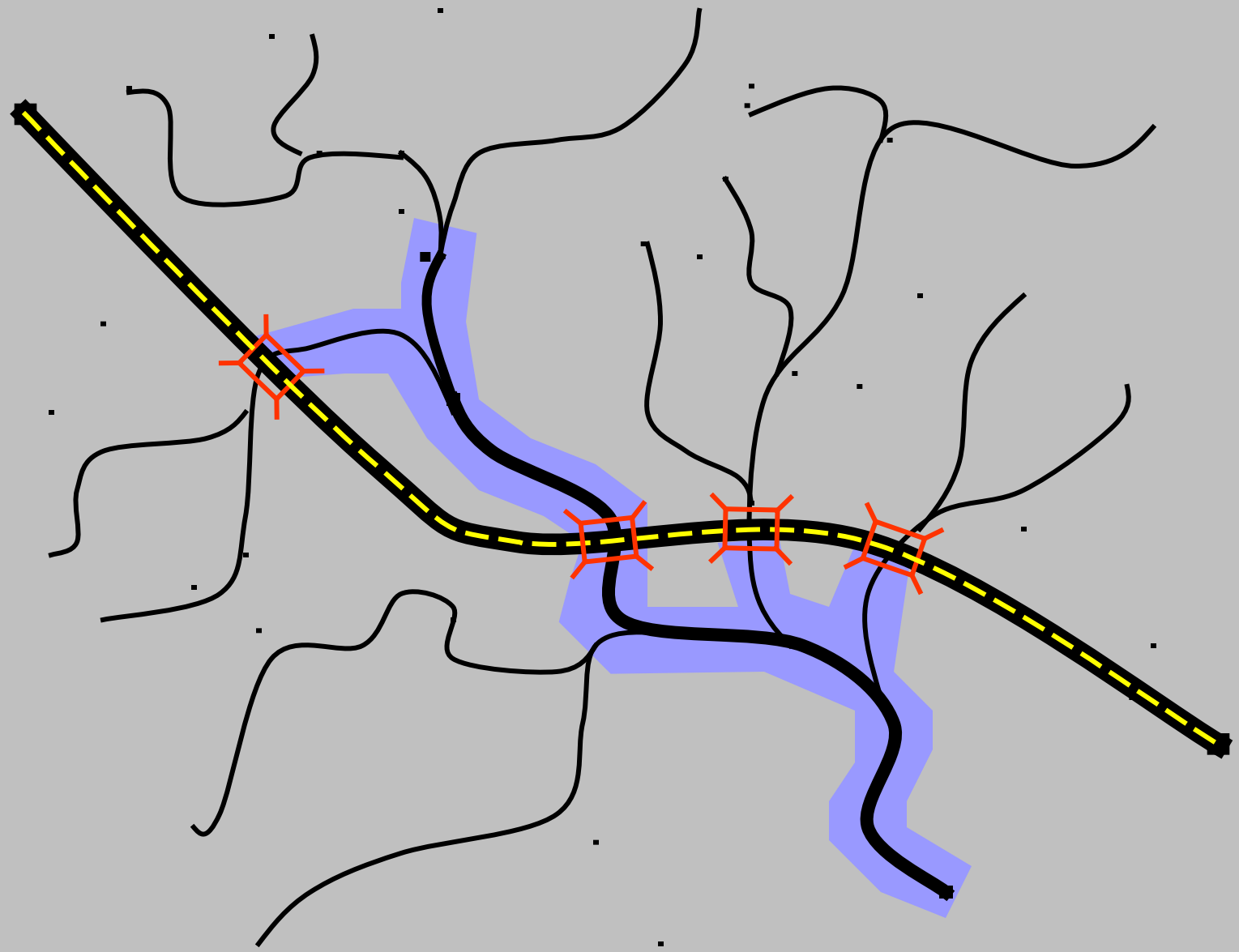


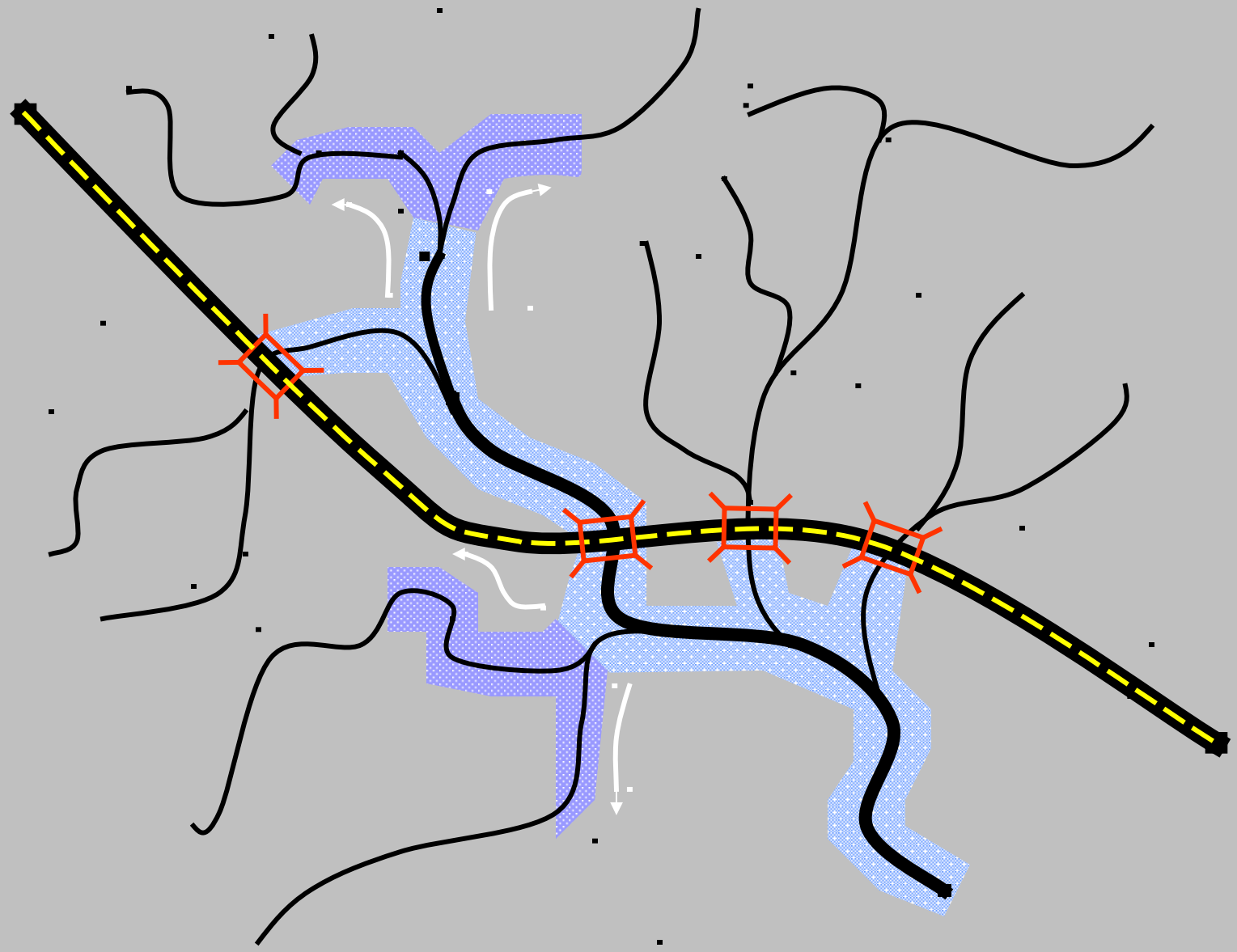


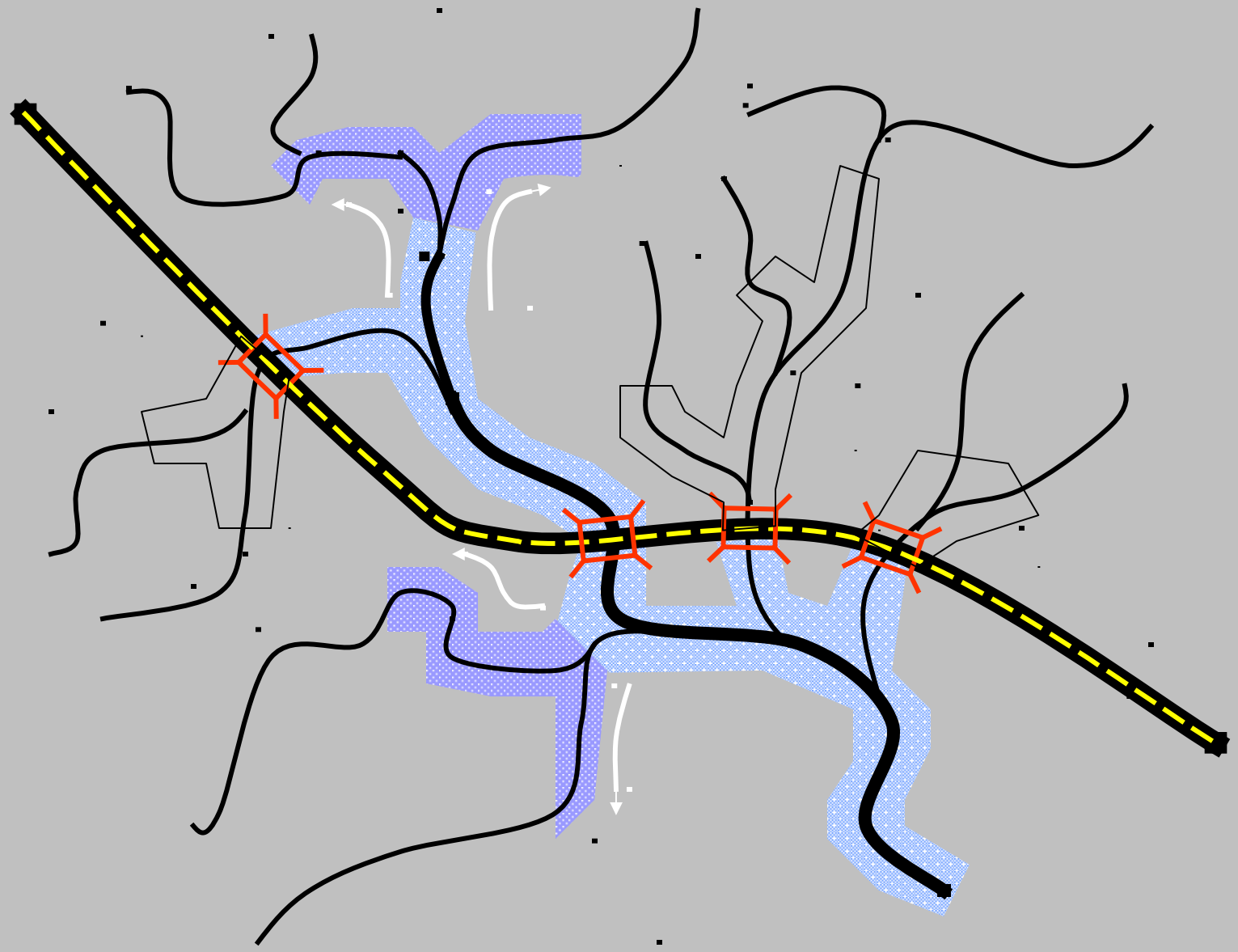






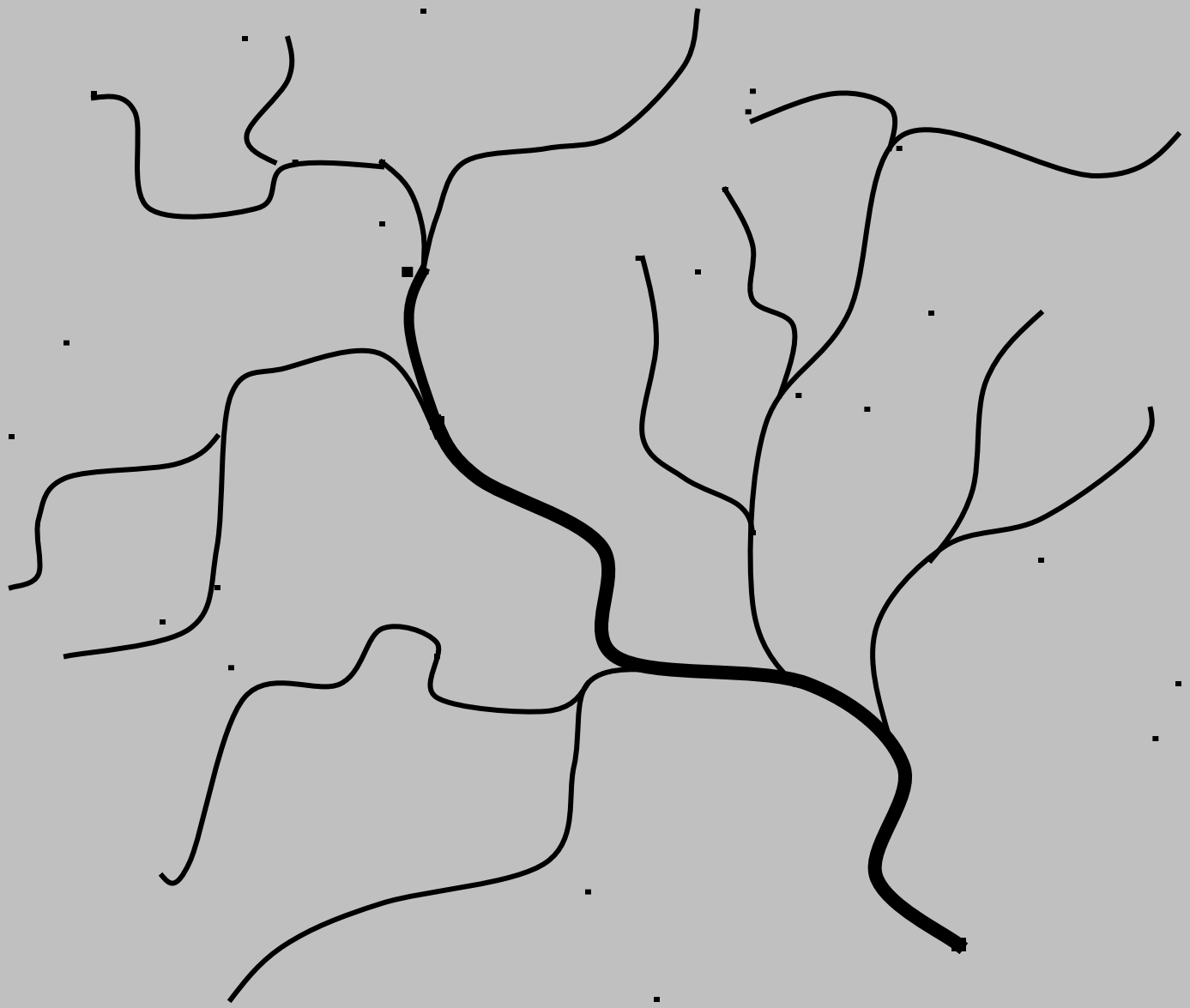


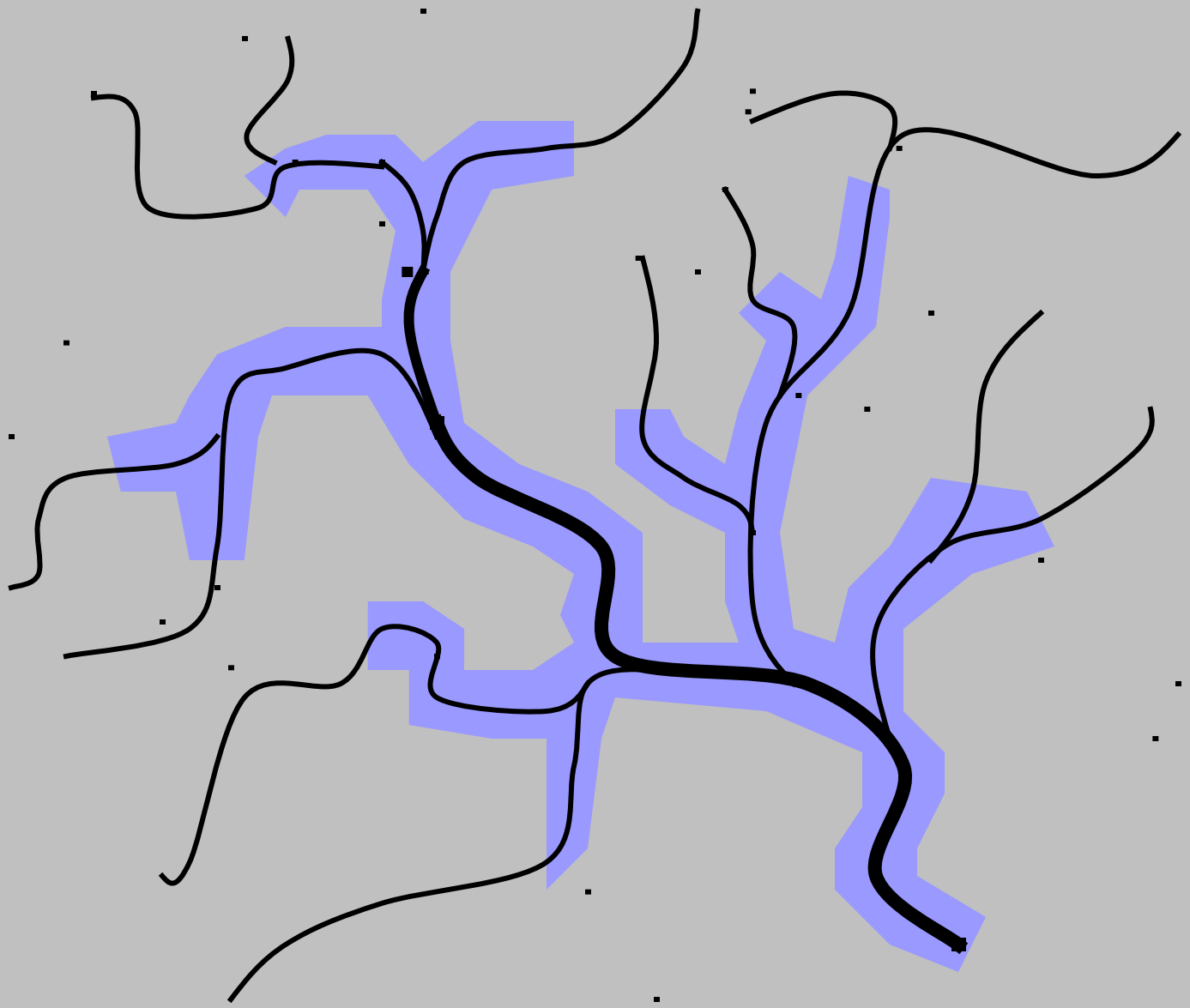


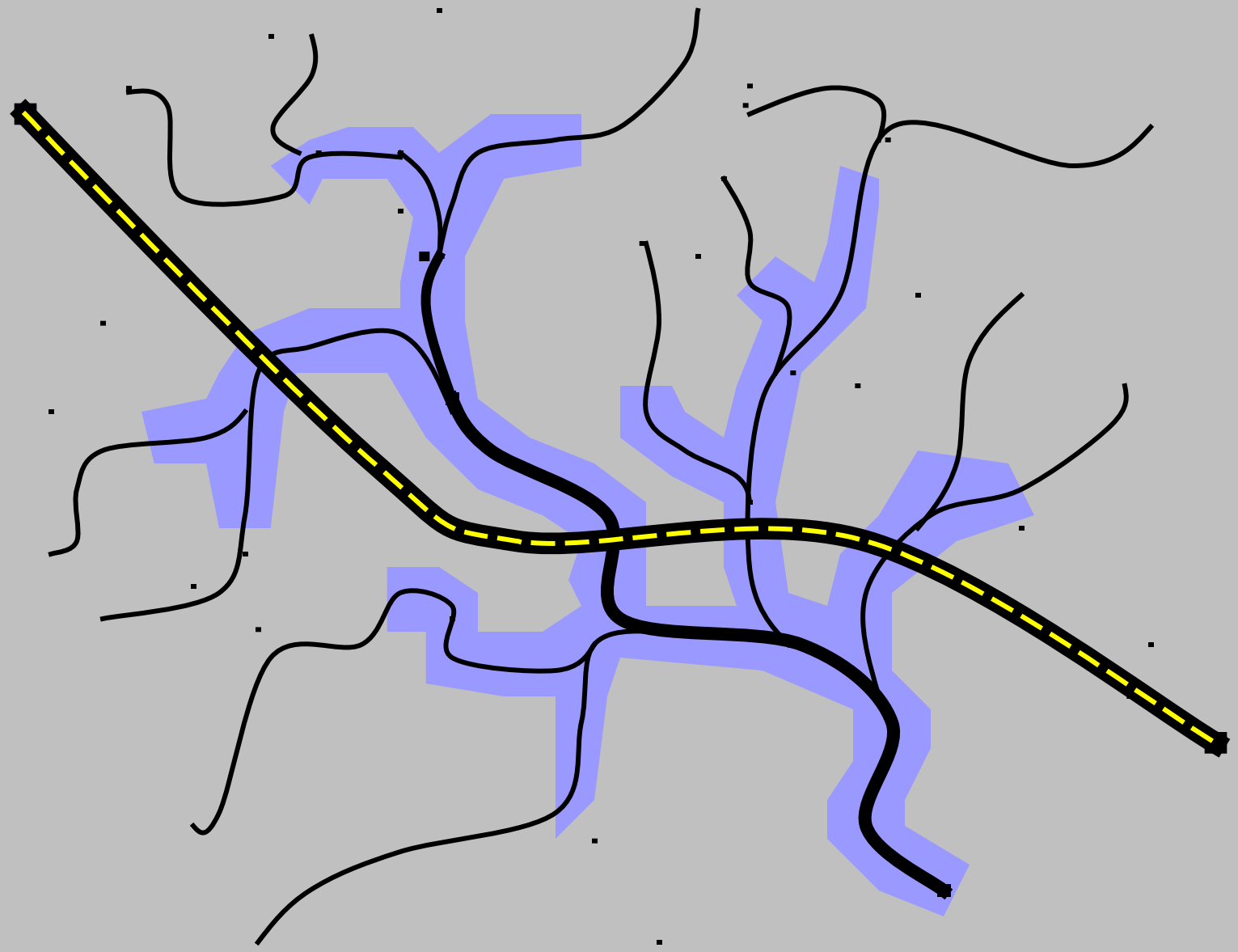


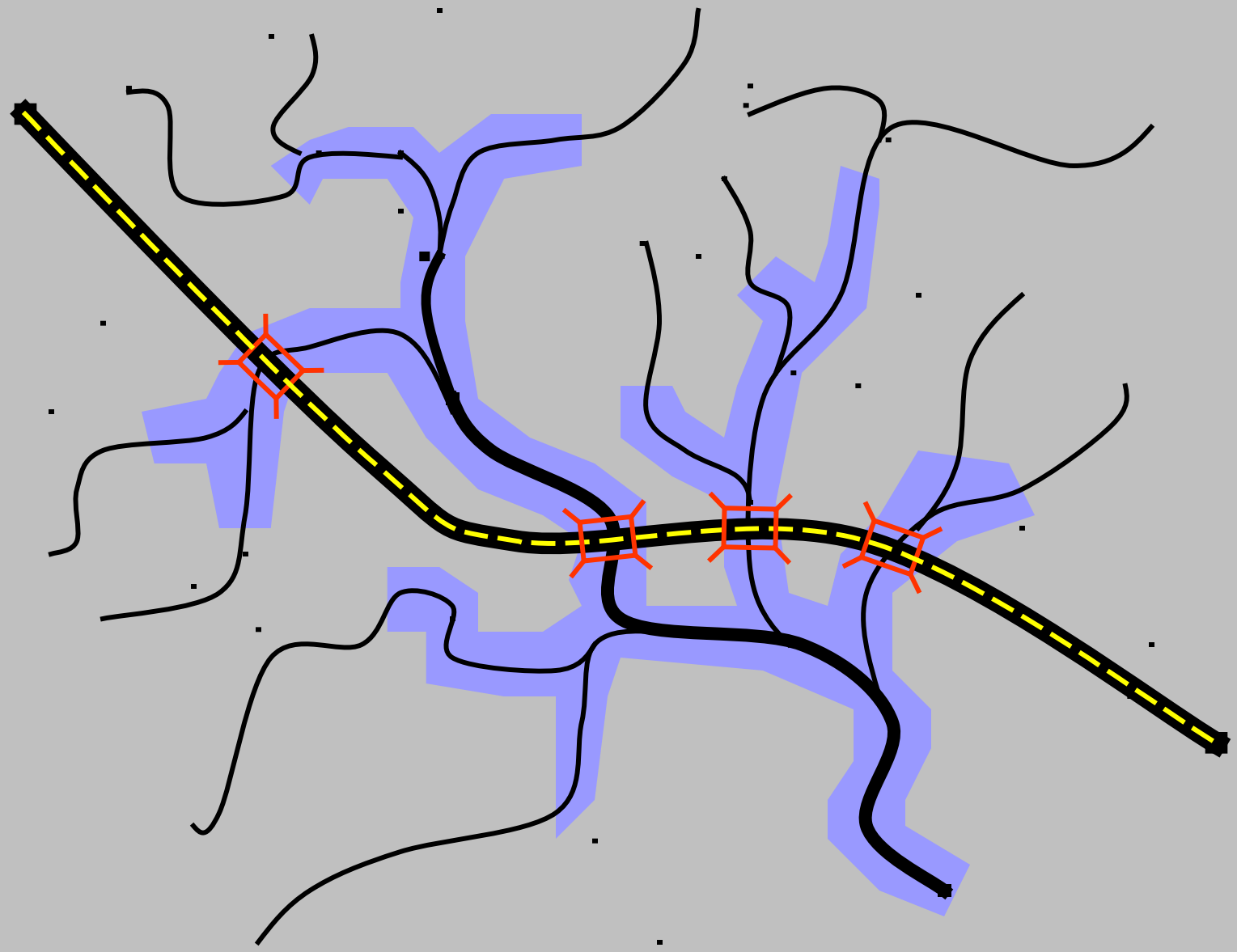
Population Fragmentation and Isolation

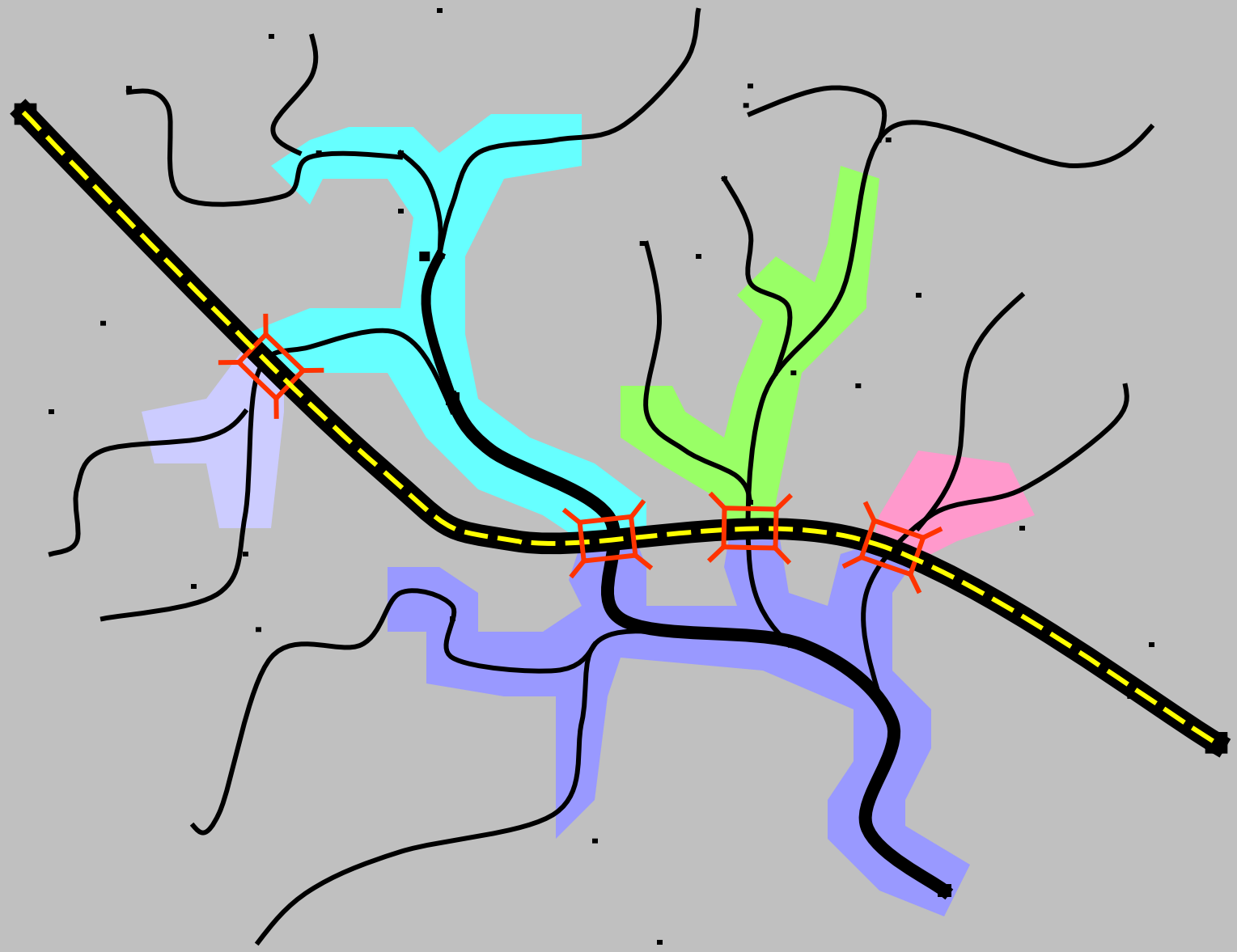
- Barriers to movement subdivide or isolate populations
- Smaller and more isolated populations are more vulnerable to:
  - extinction due to chance events
  - genetic changes

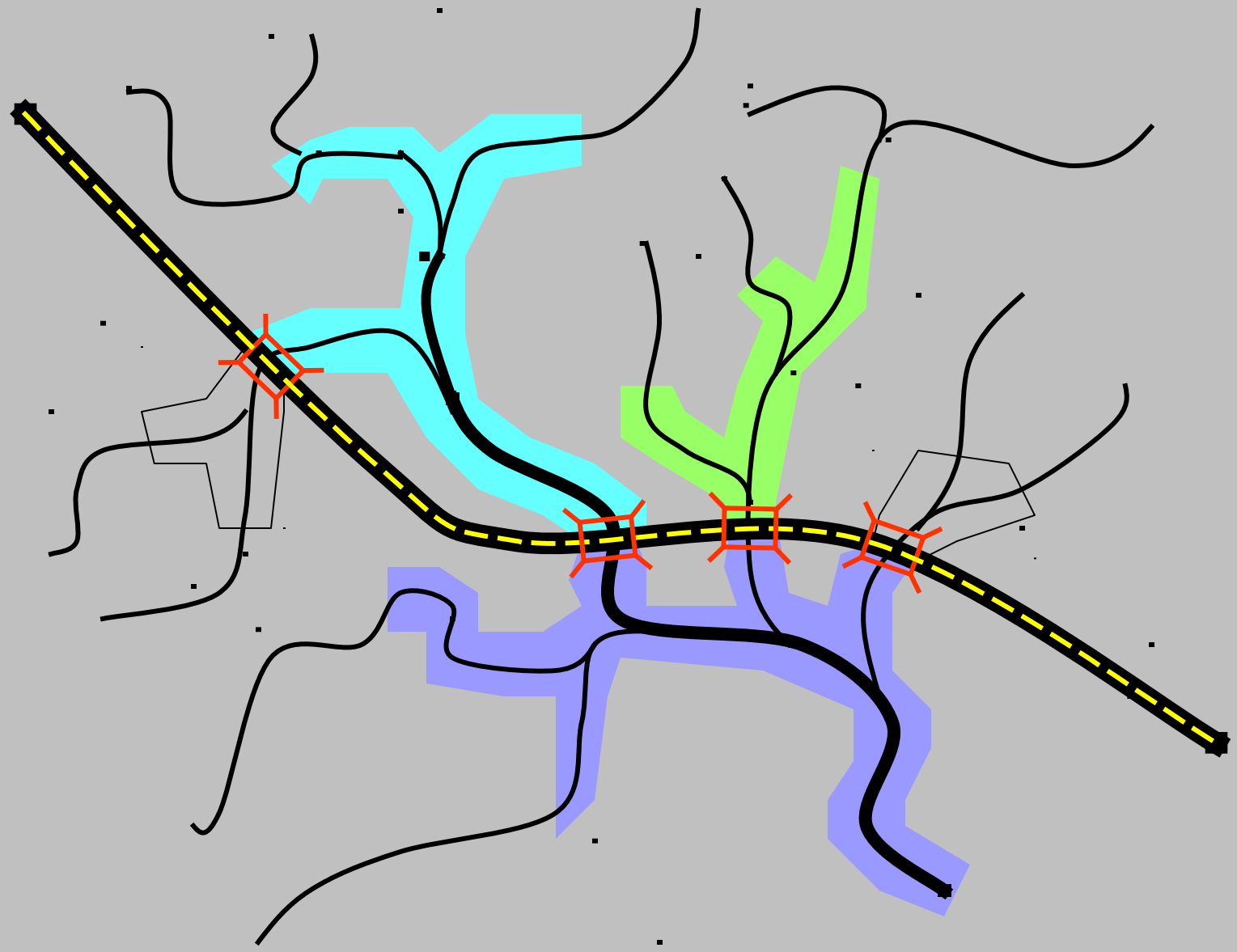


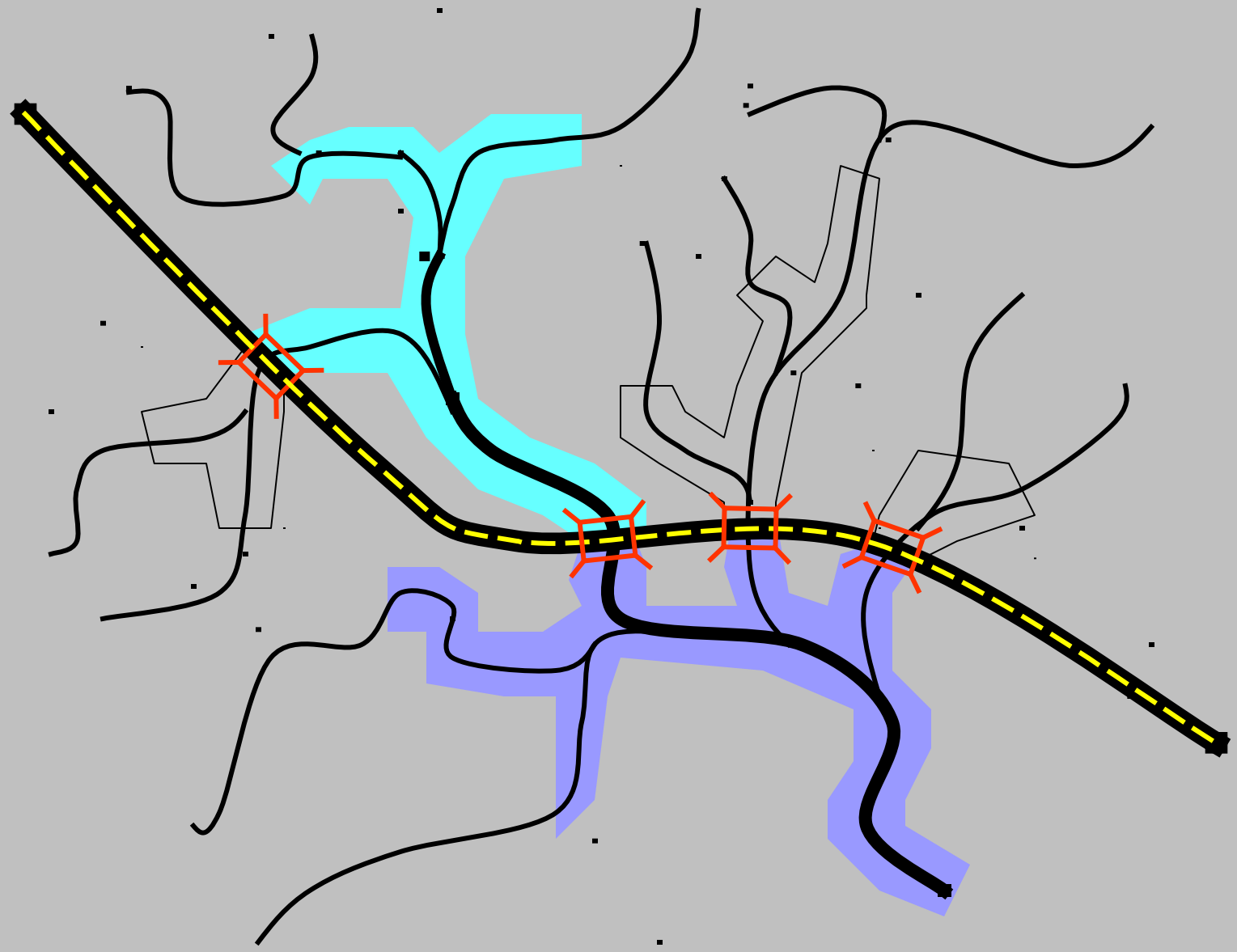






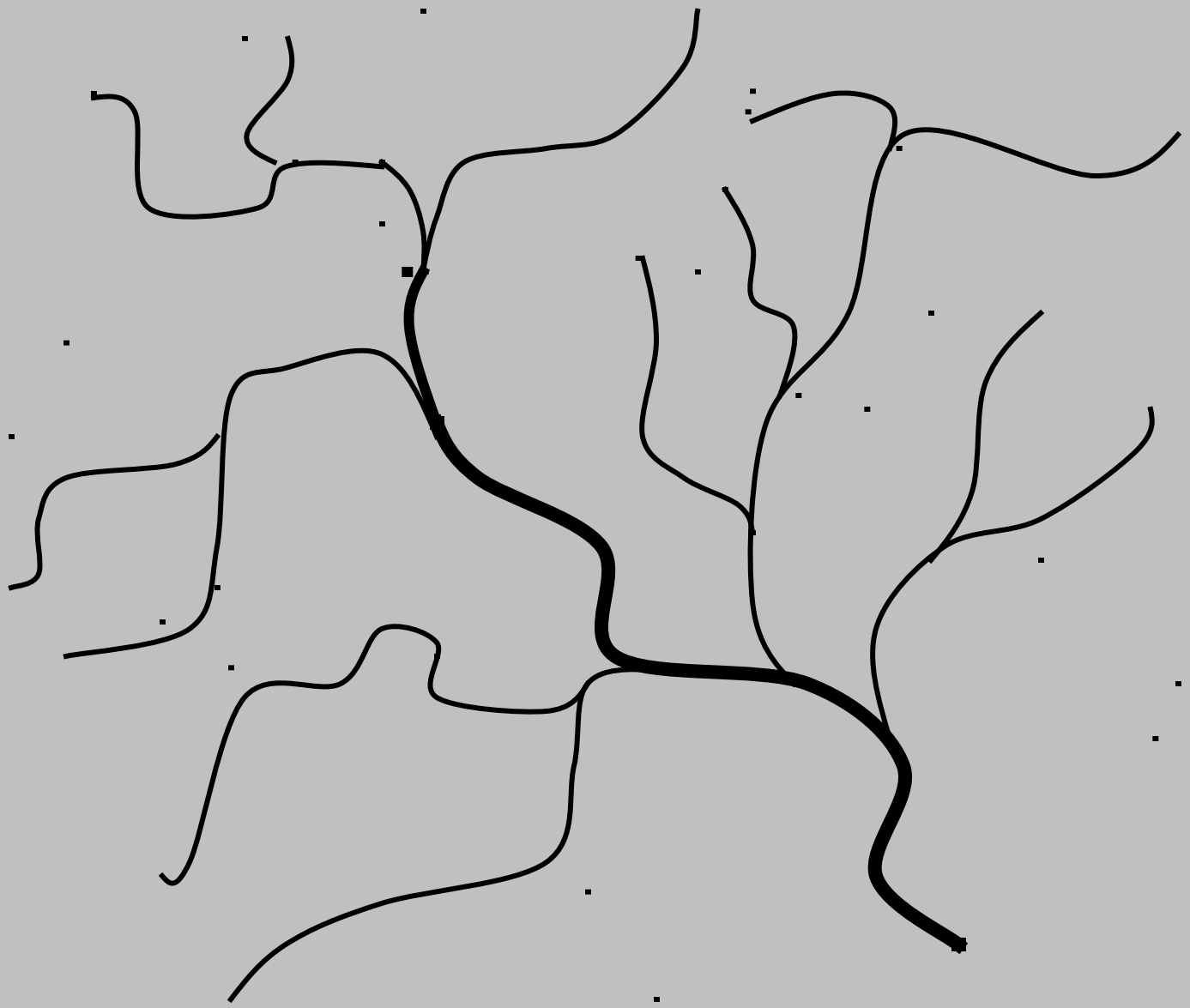


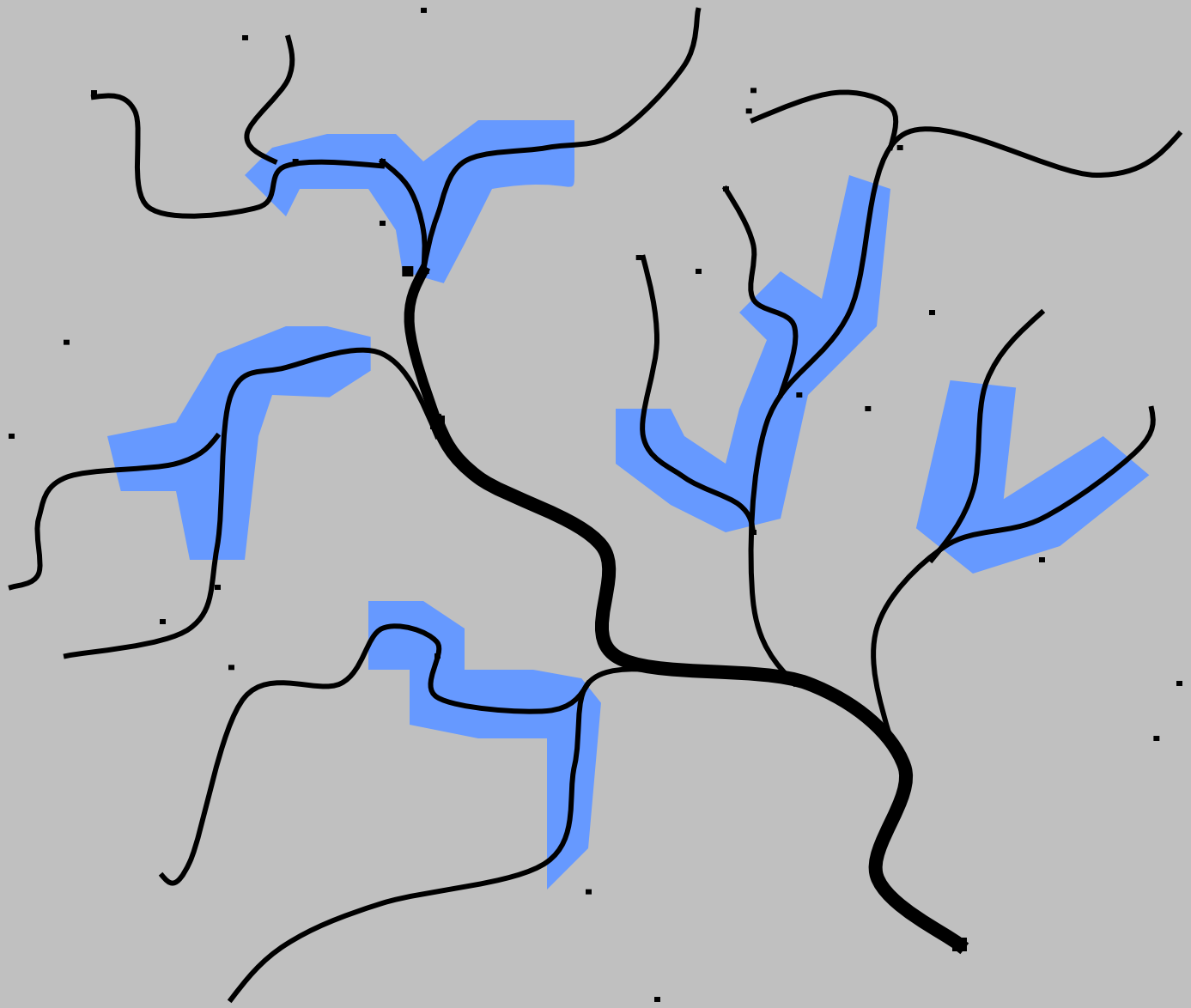


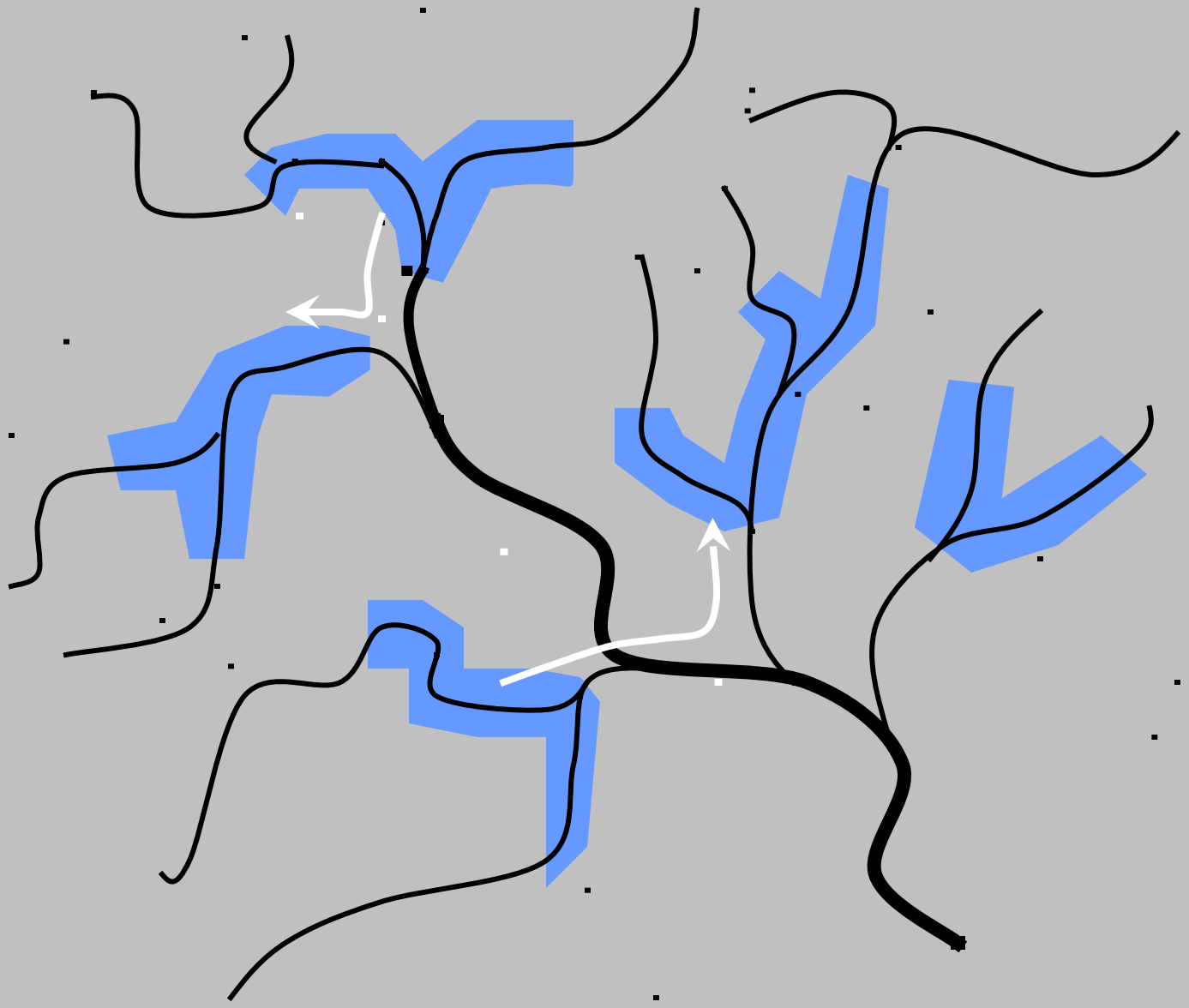


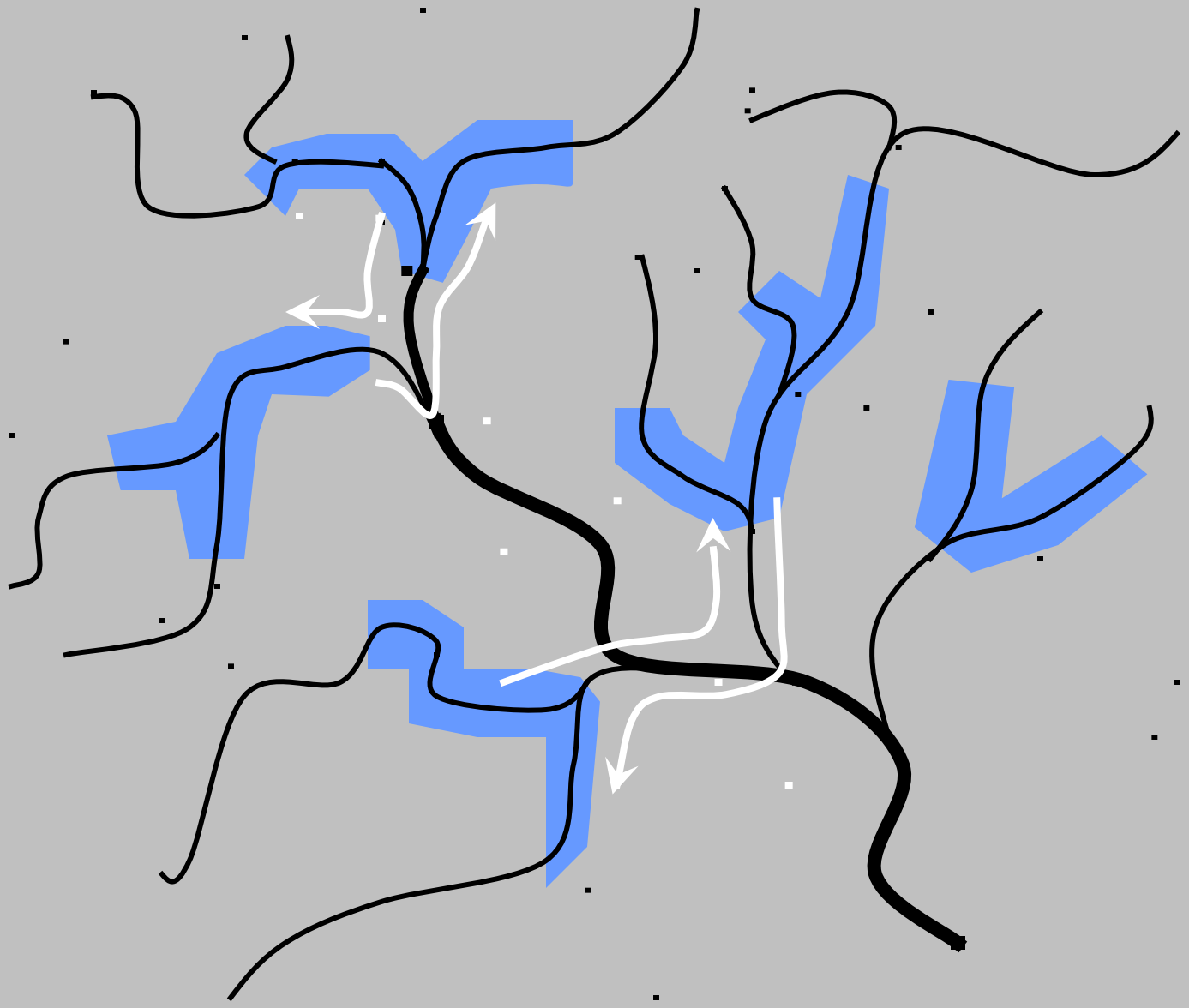
Processes that Maintain Regional Populations ("Metapopulations")

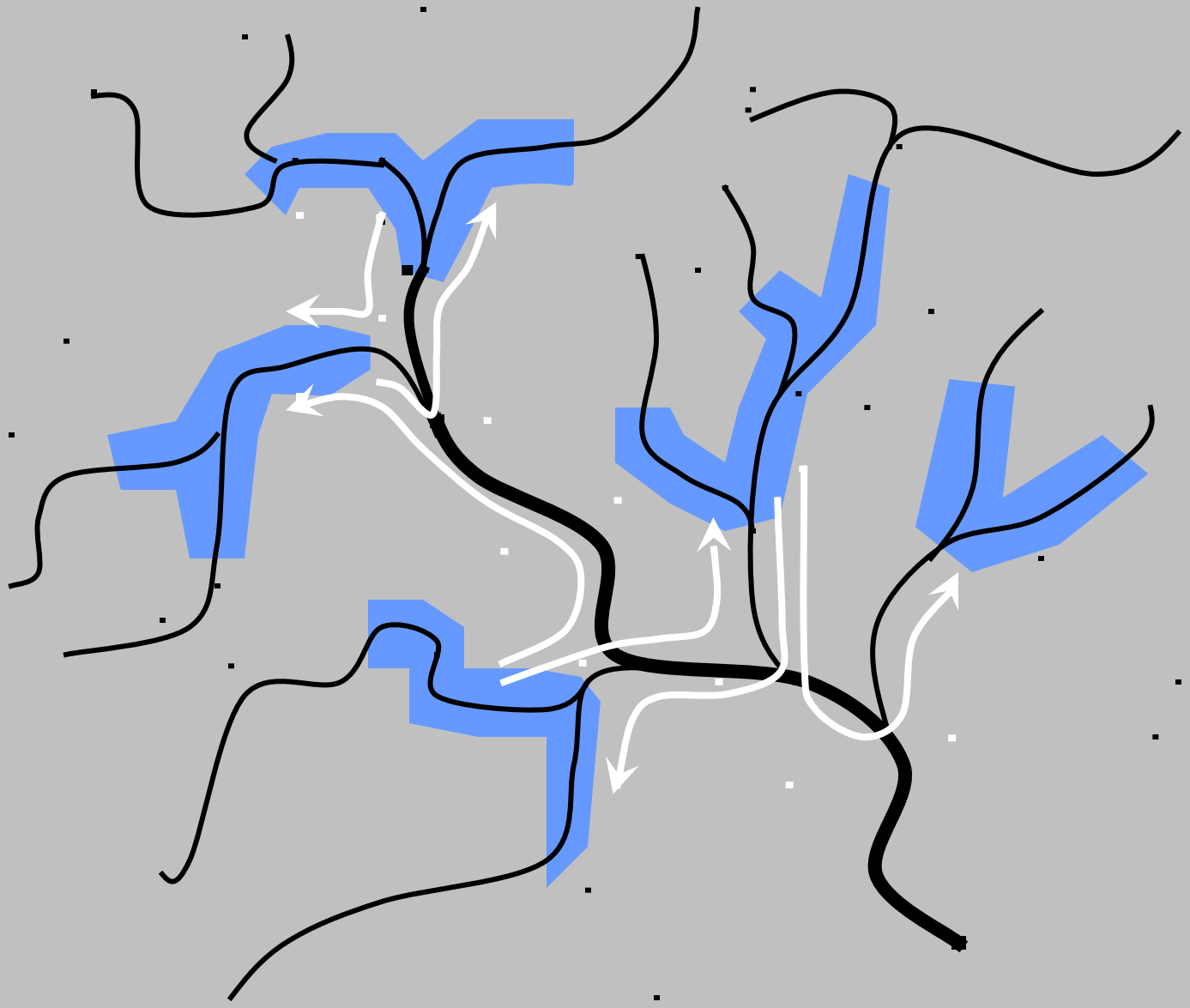
- Supplementation ("rescue effect")
- Gene flow
- Re-colonization

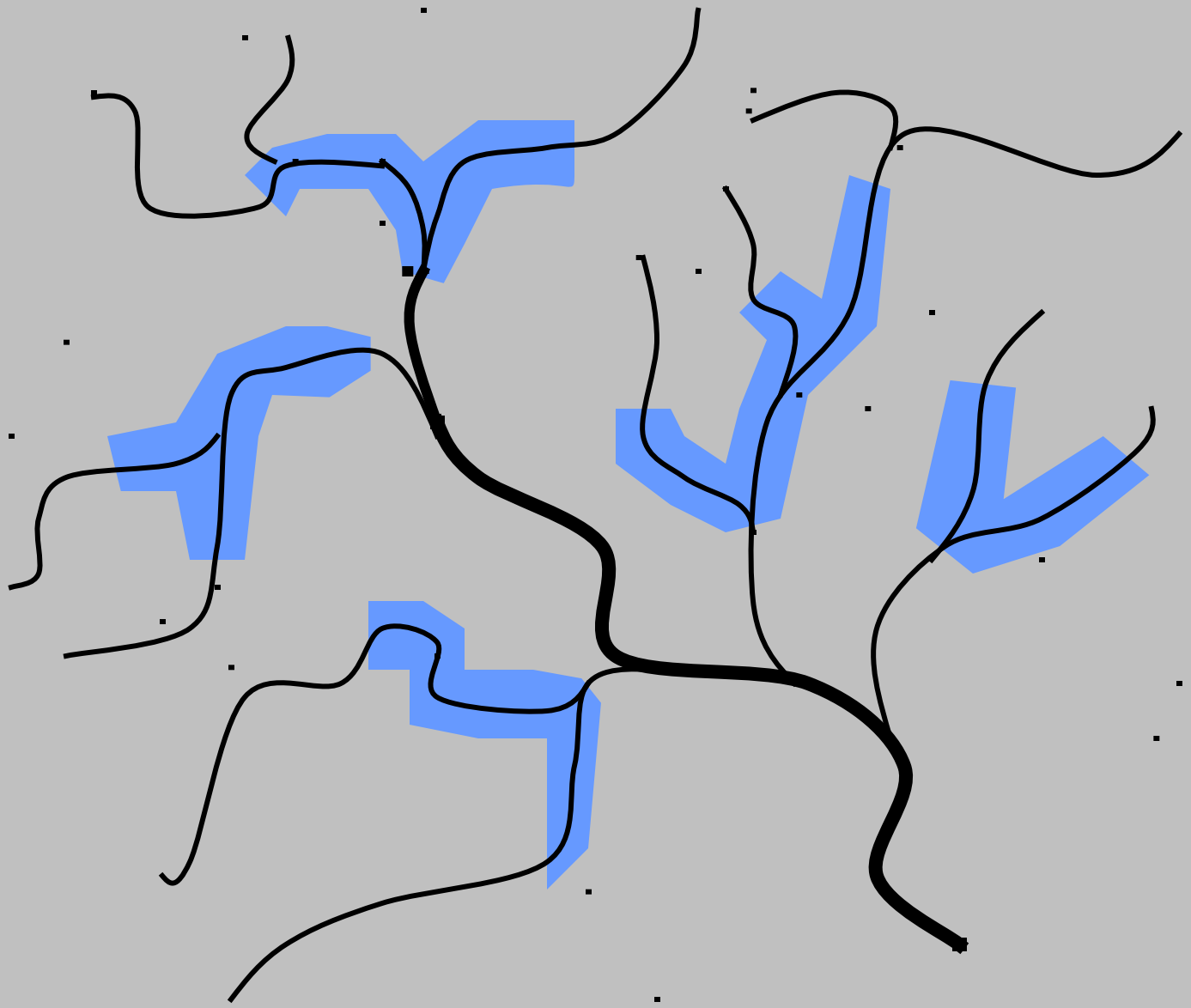


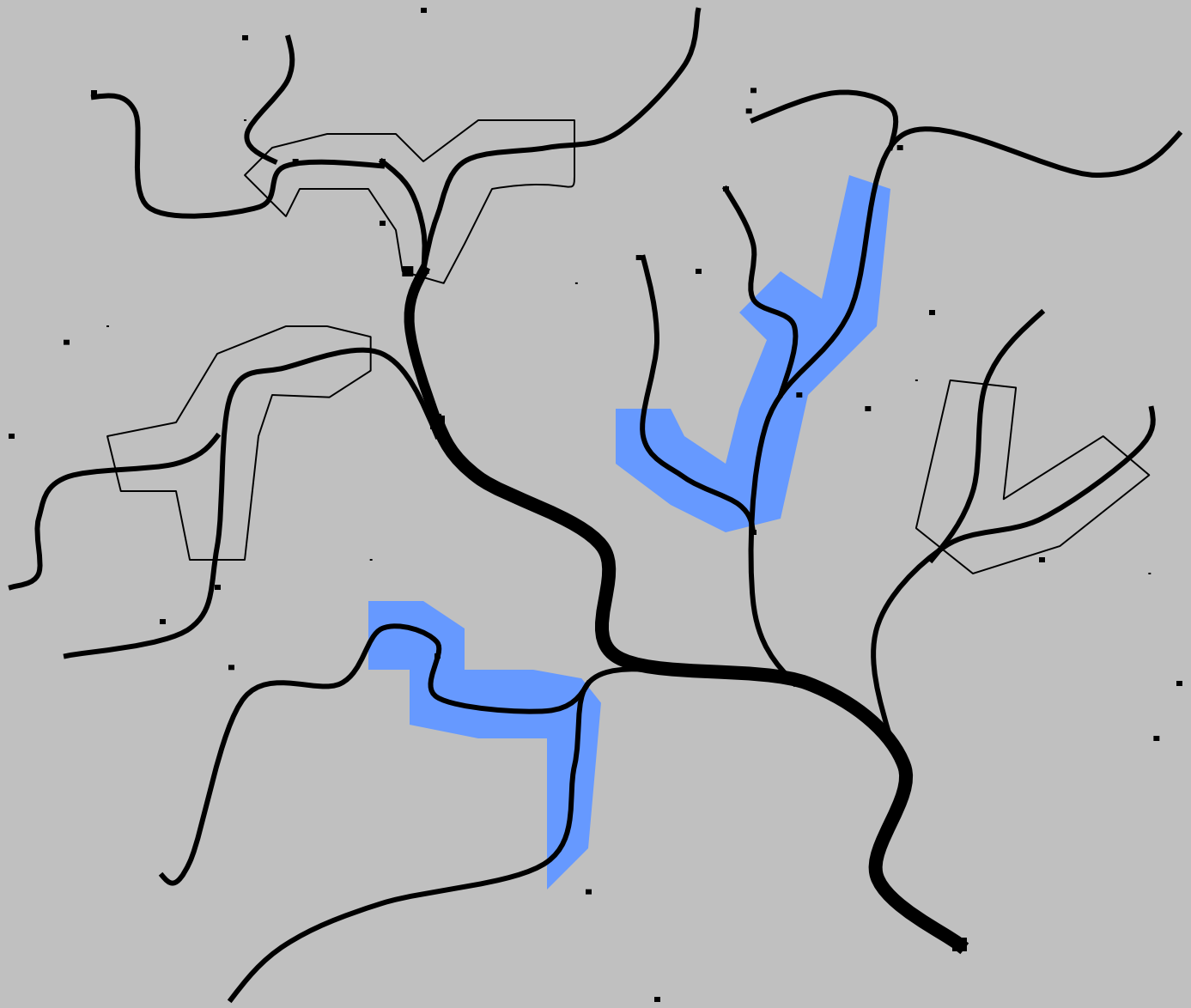


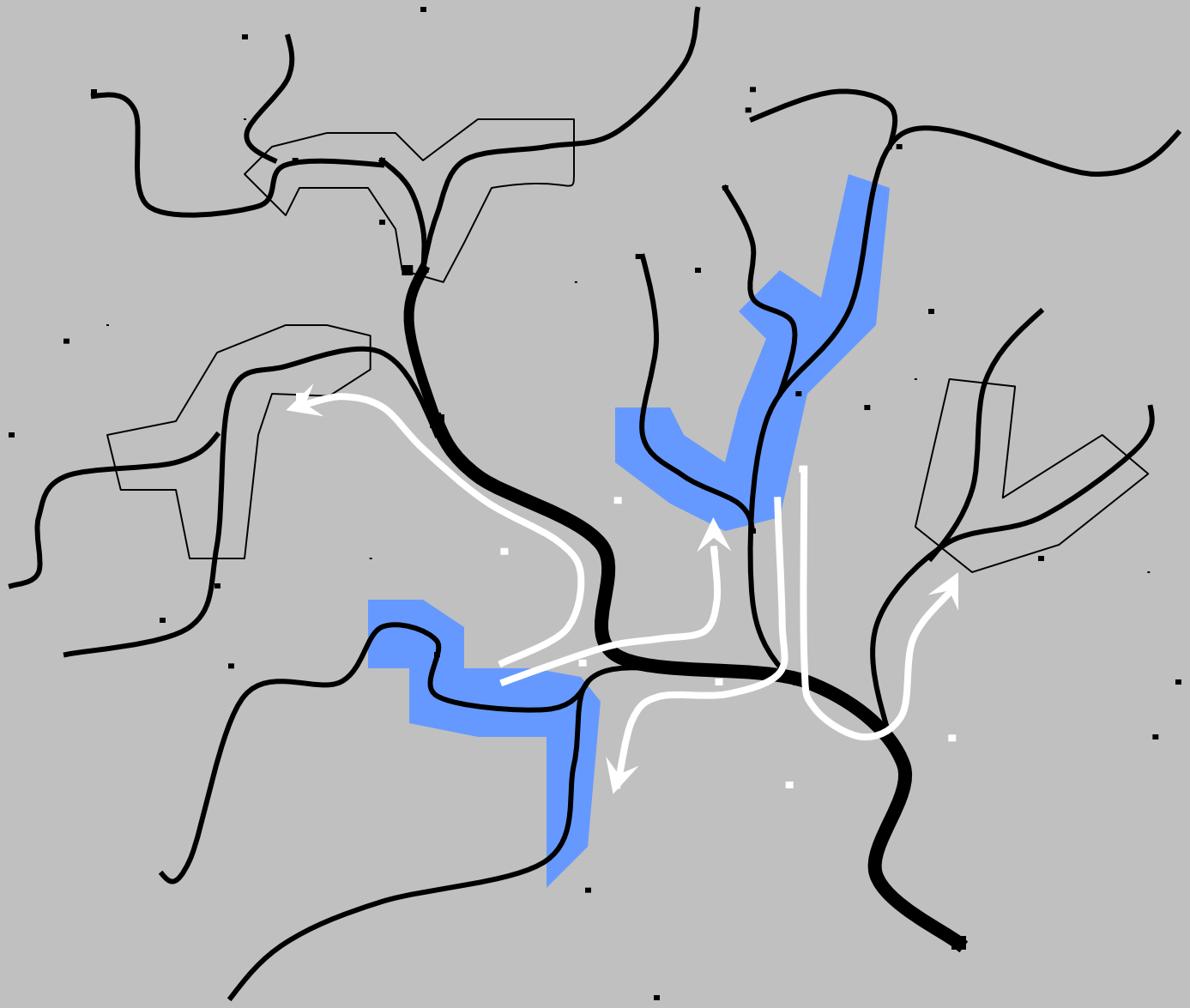


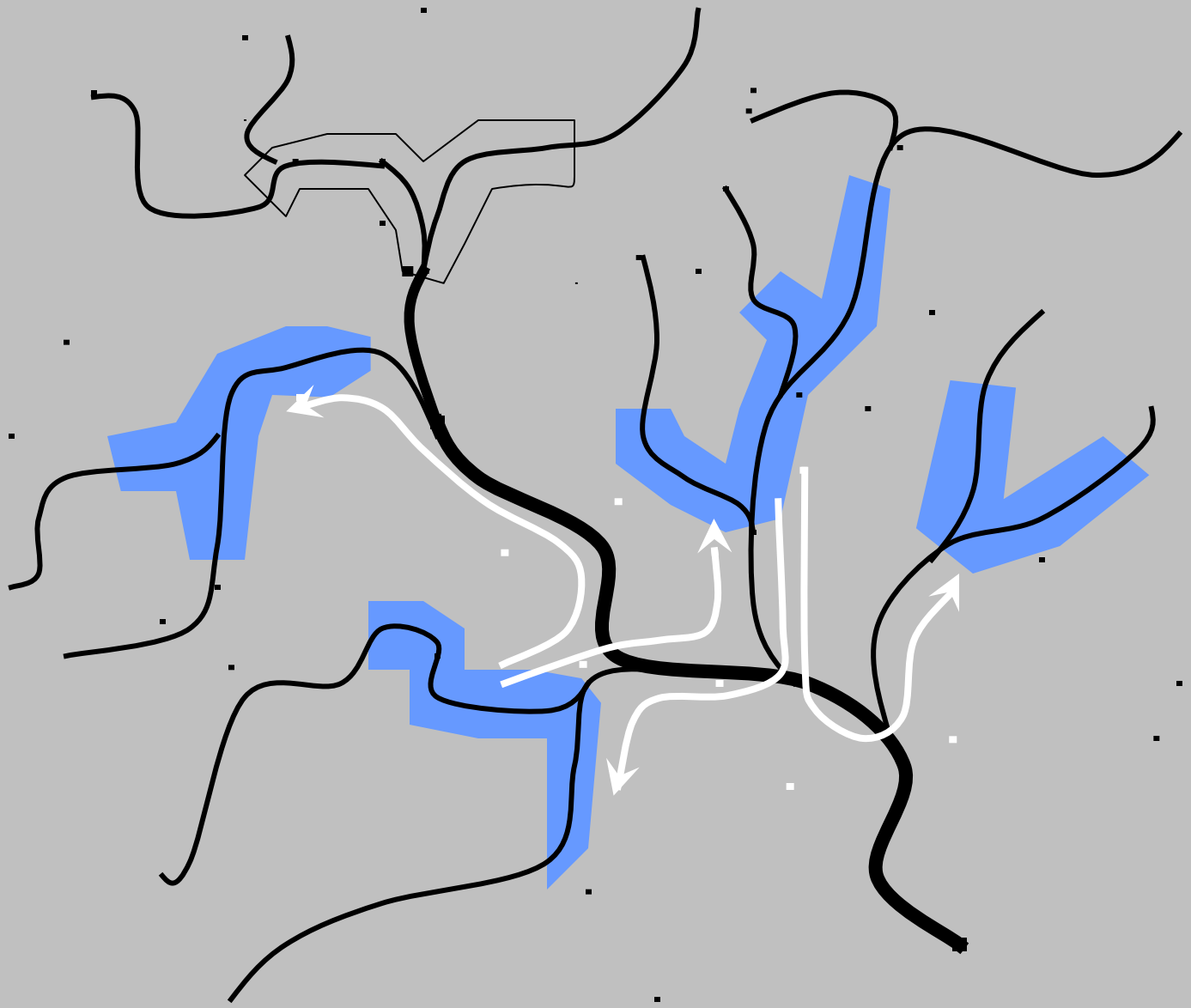


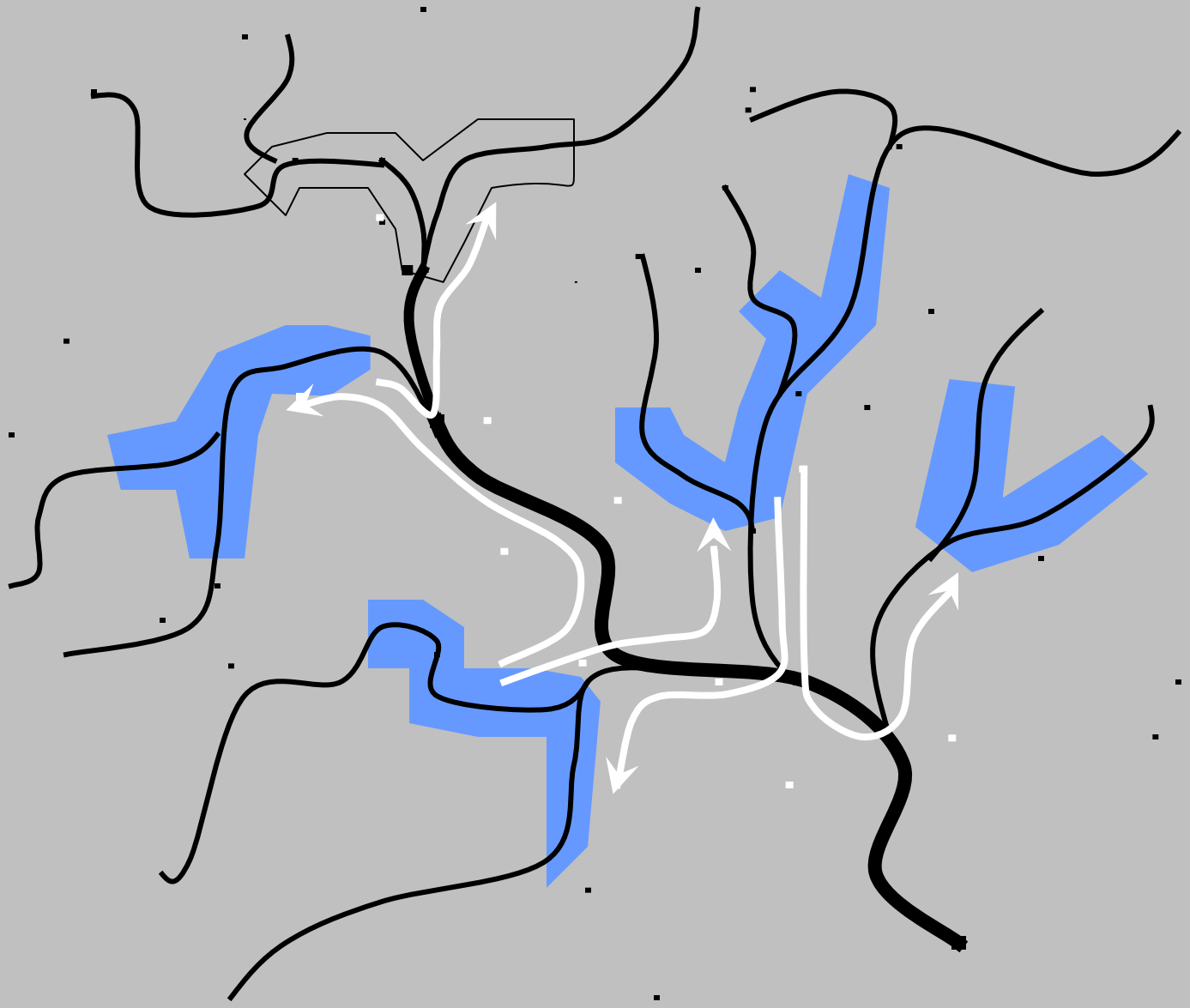


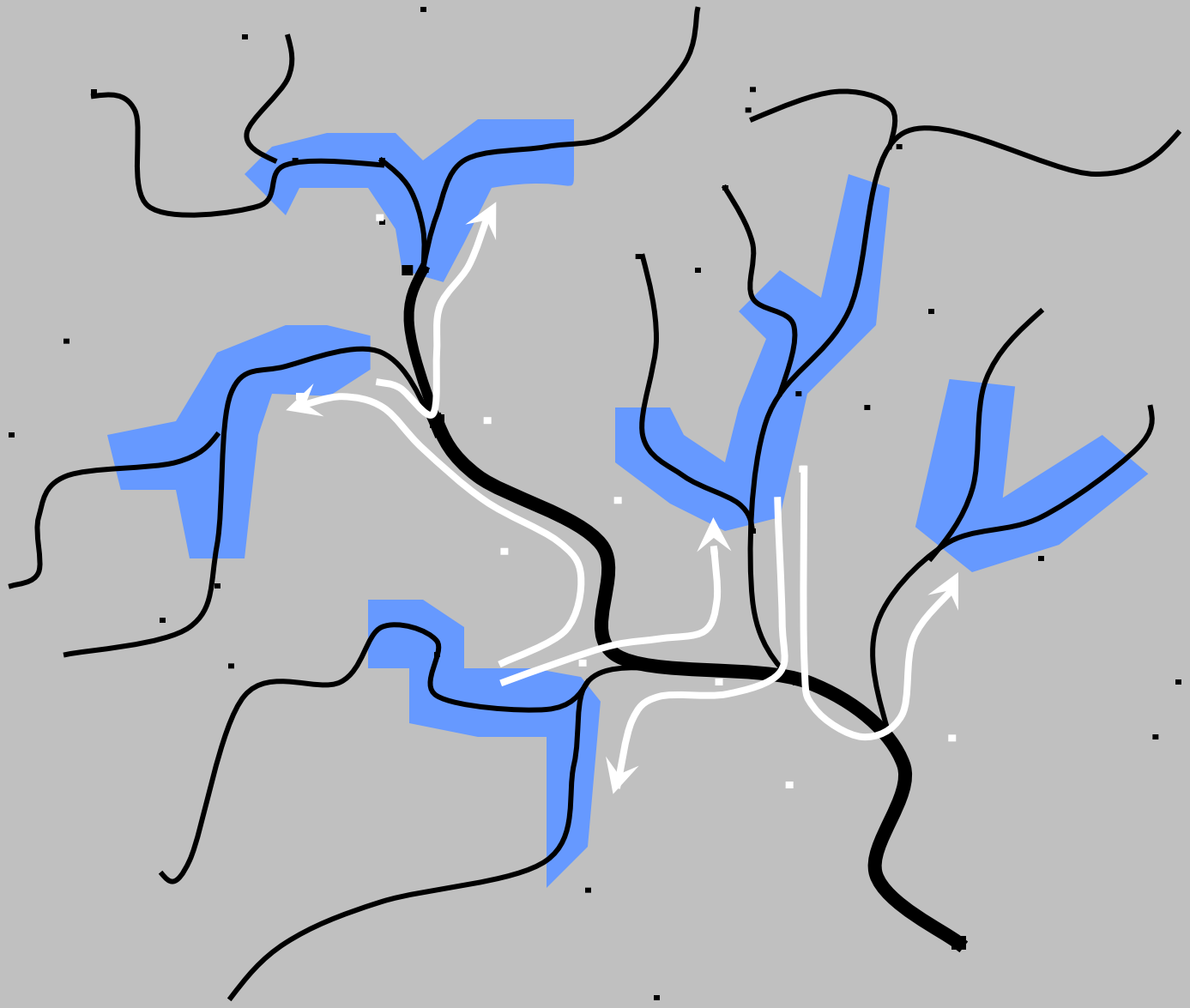


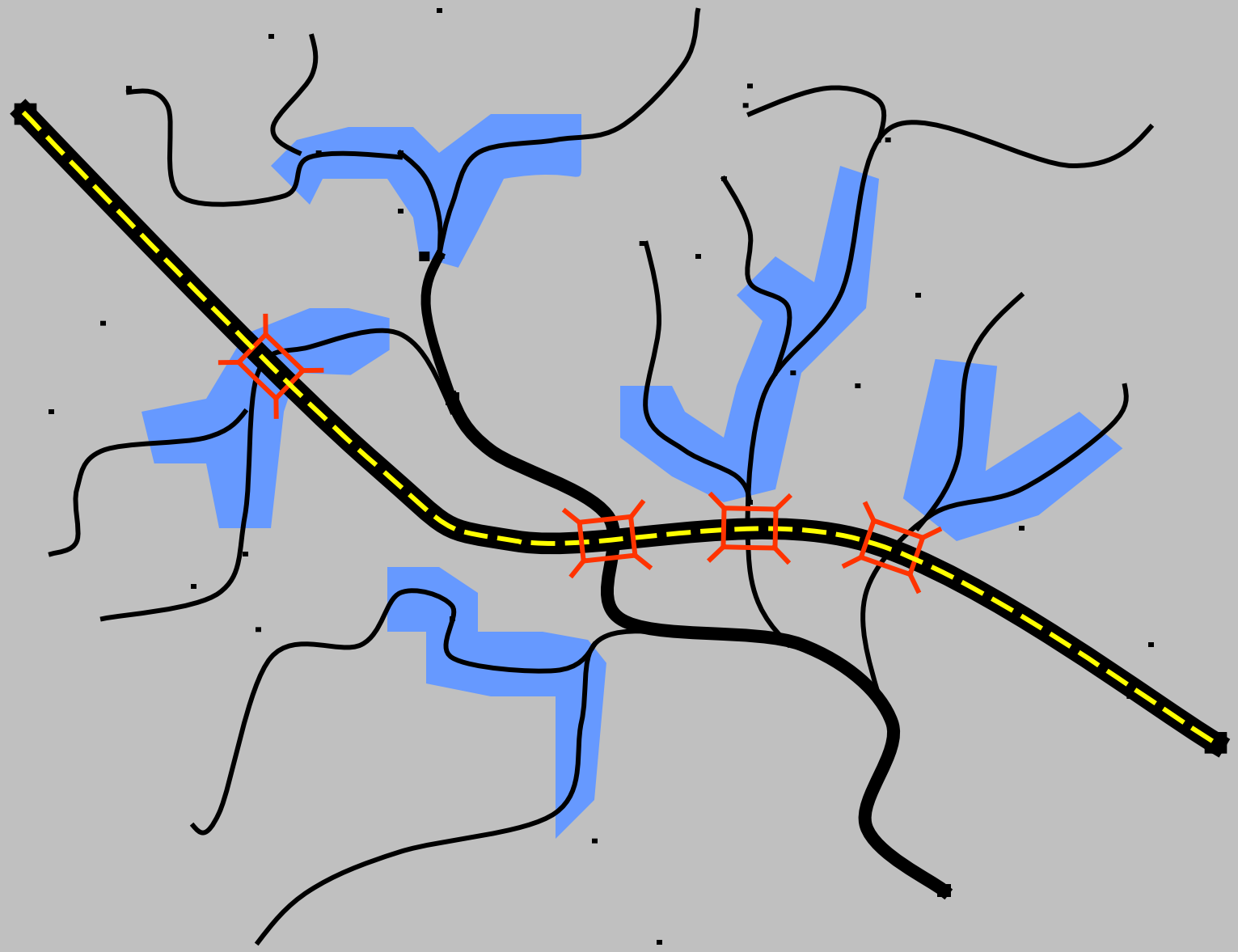


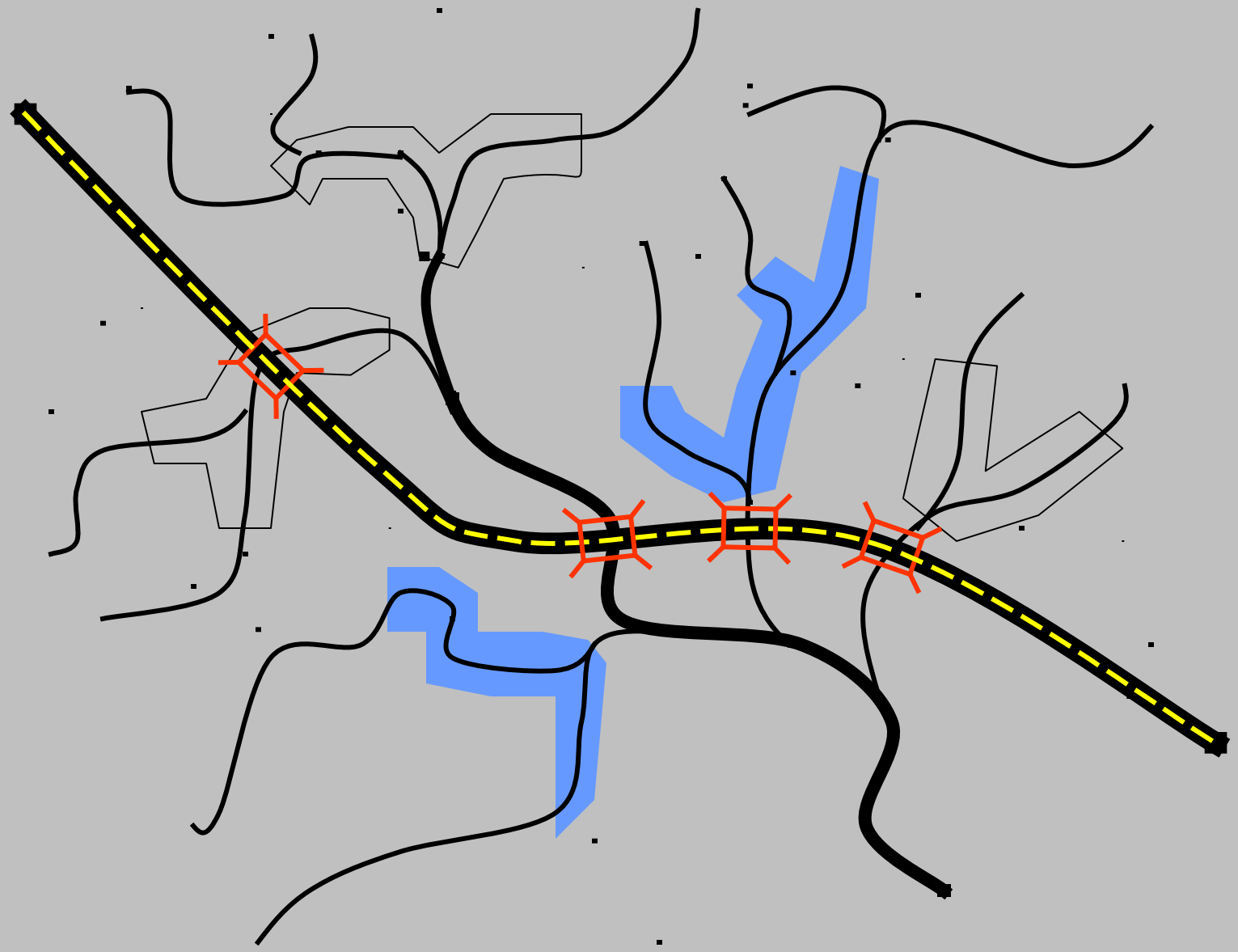


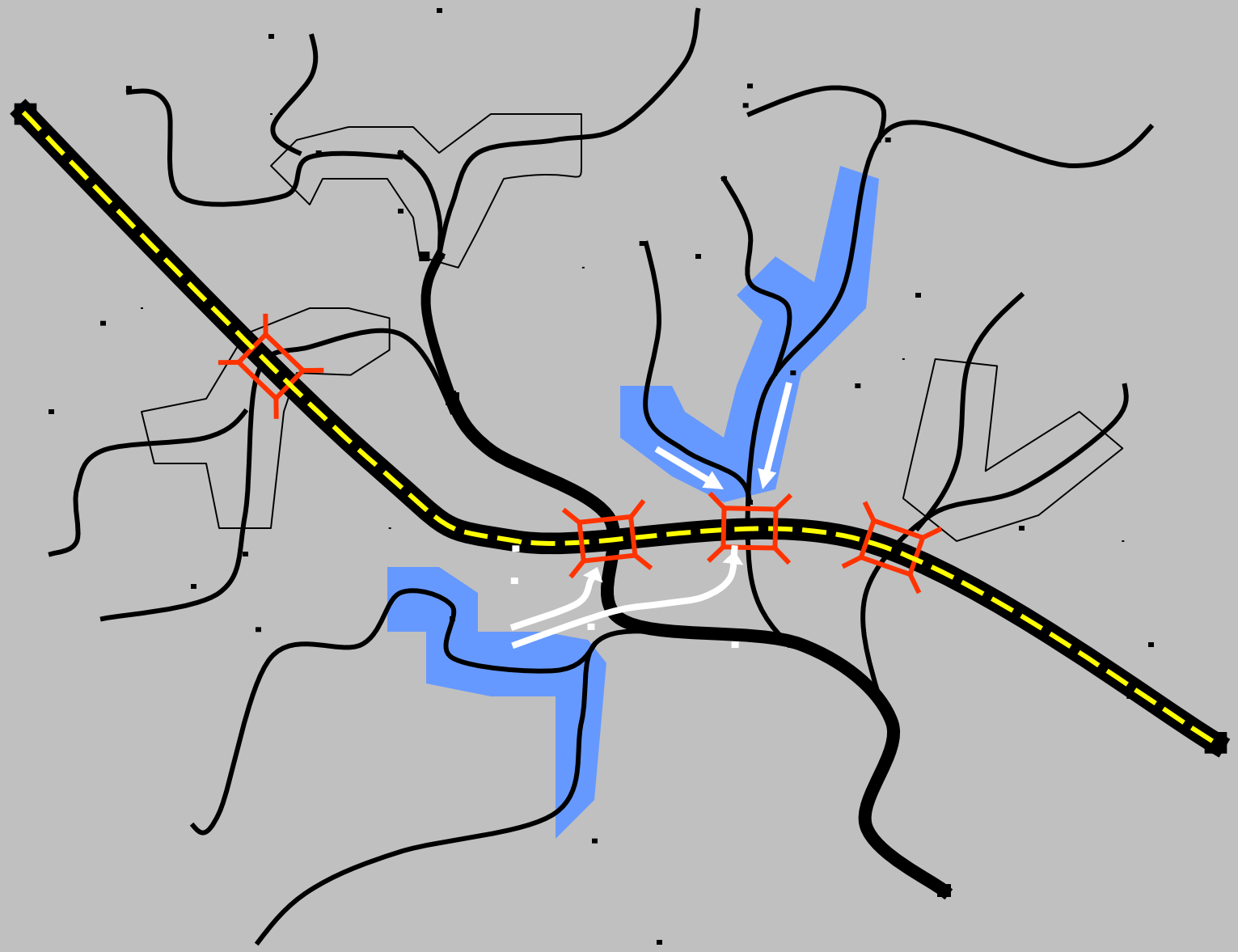












Wood turtle
Scott Jackson

Beaver

Muskrat
© 2003 John White

Scott Jackson
Snapping turtle

Star-nosed mole
Kenneth Catar

Otter

Spring Salamander

Scott Jackson
Dusky salamander

Mink

Importance of Small Streams

- Make up a large percentage of stream miles
- Cumulatively provide more habitat than large rivers
- Support species not found in larger streams and rivers
- Provide important spawning & nursery habitat for fish

Glimpse of Existing Situation

A 2004 - 2006 survey of 465 single culverts in VT

from streams with drainage areas >0.25 mi^2:

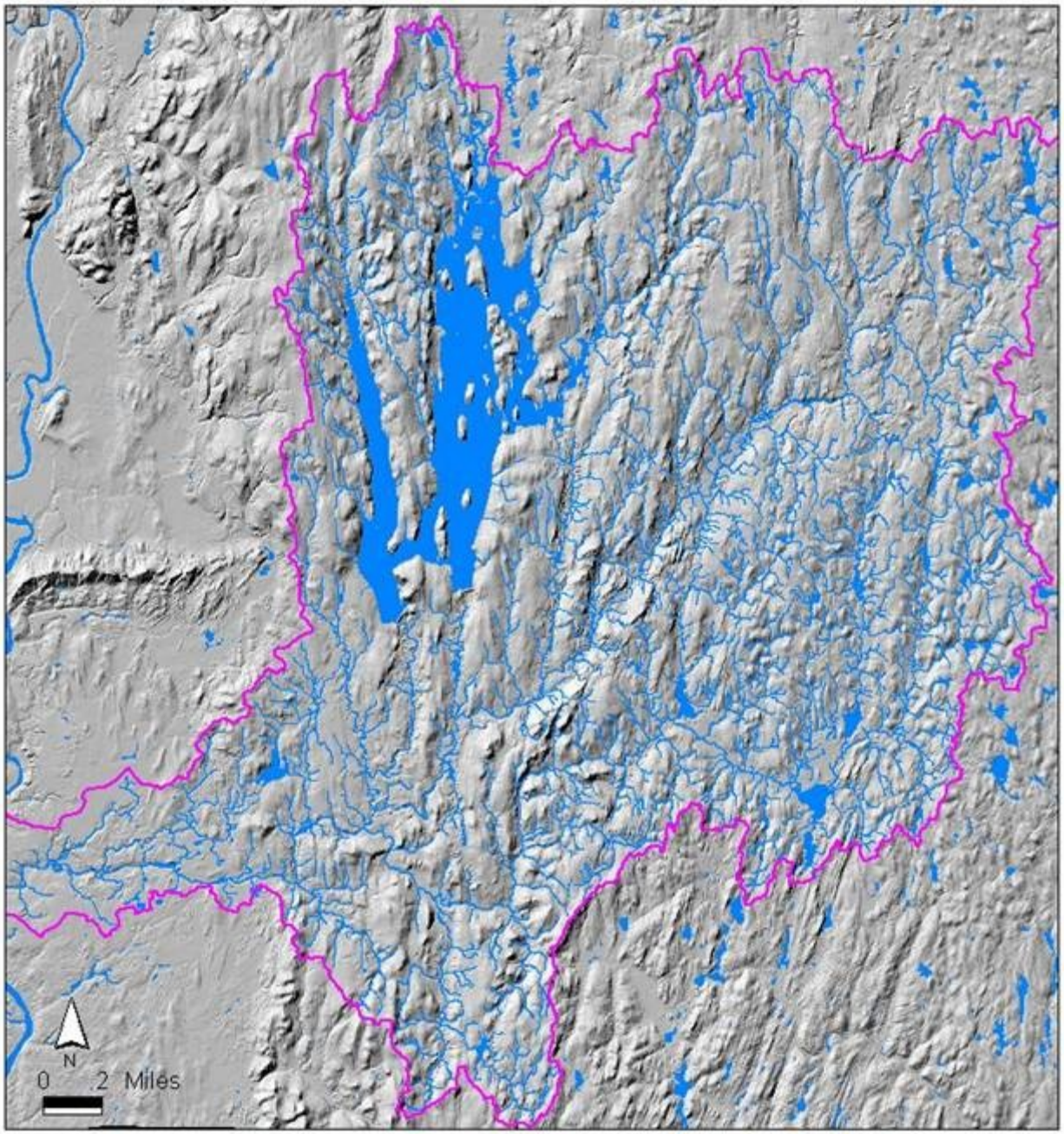
- **52% (241) Impassable to all or some aquatic organisms (culverts with an outlet drop)**
- **47% (217) Partial Barrier (indeterminate – needs further evaluation)**
- **1% (7) Passable (stream substrate throughout culvert, no outlet drop, no inlet obstruction)**

Glimpse of Existing Situation

A survey of 1,554 single and multiple culverts in five New England states:

	Number	Percent
Severe barrier	736	47.4
Moderate barrier	418	26.9
Minor barrier	399	25.7
Full AOP	1	<0.1
AOP + sm. wildlife	0	0
AOP + lg. wildlife	0	0

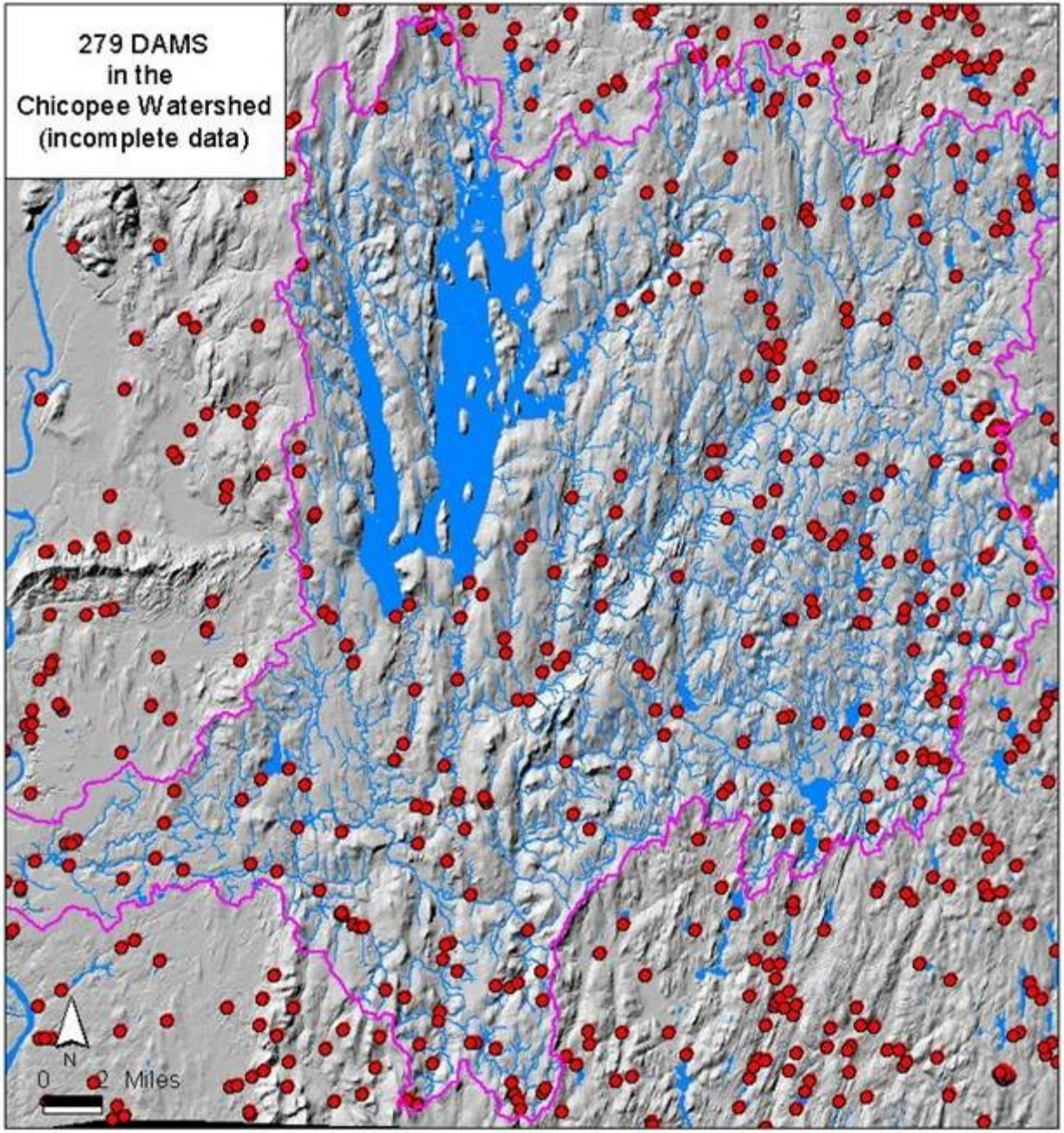
CHICOPEE WATERSHED



721 sq.m

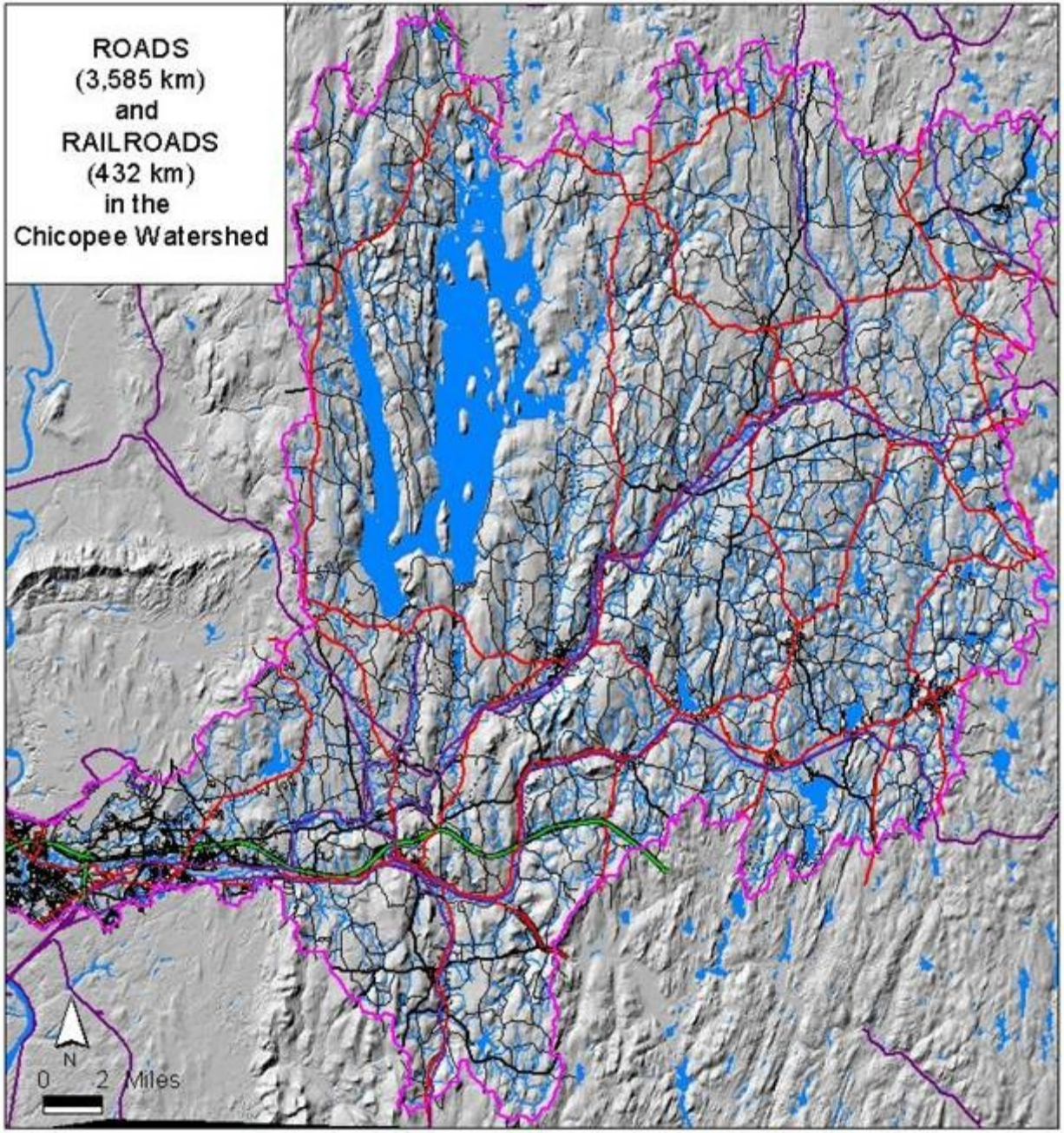
Source:
MA Riverways
Program

CHICOPEE WATERSHED



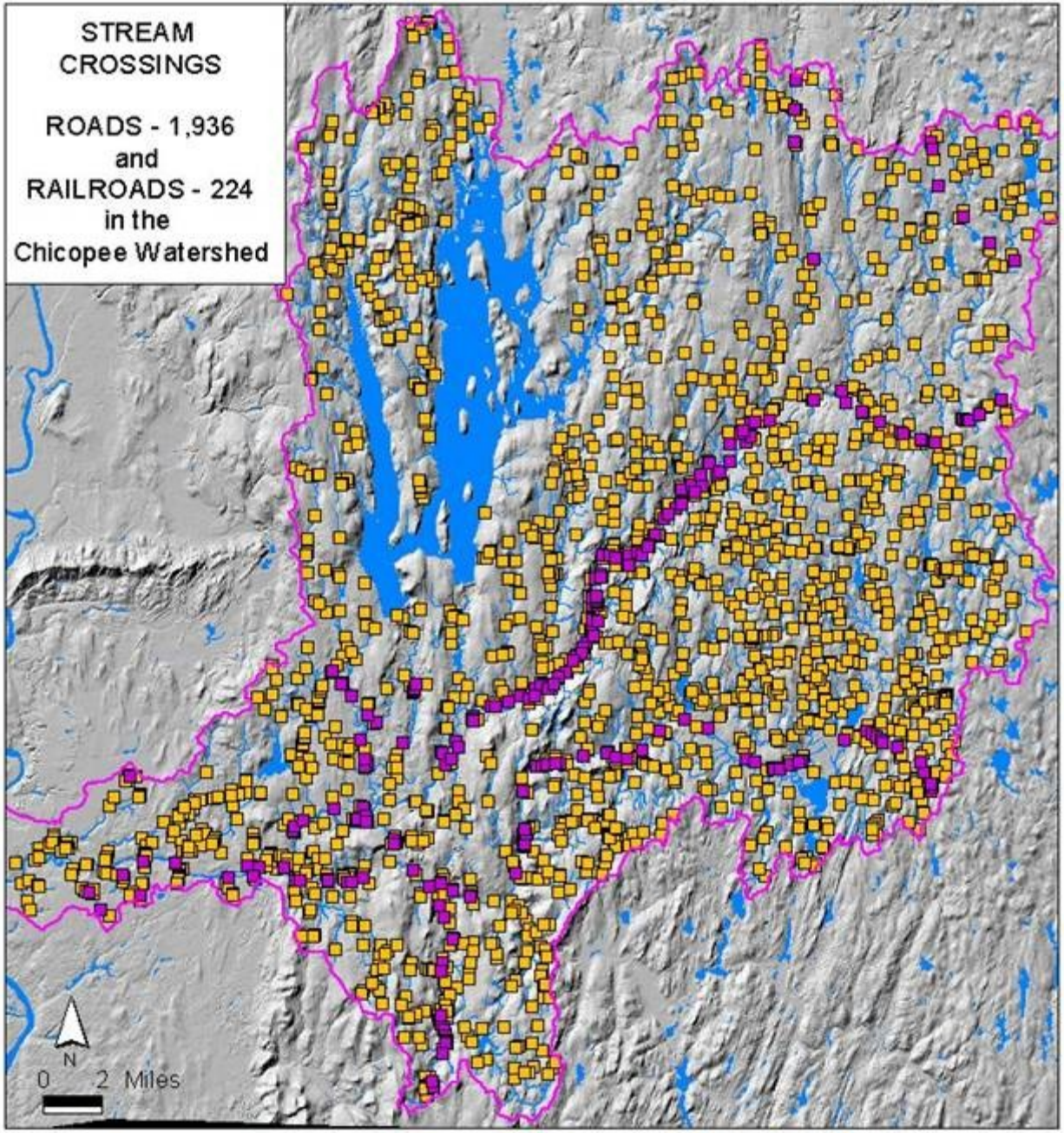
Source:
MA Riverways
Program

CHICOPEE WATERSHED



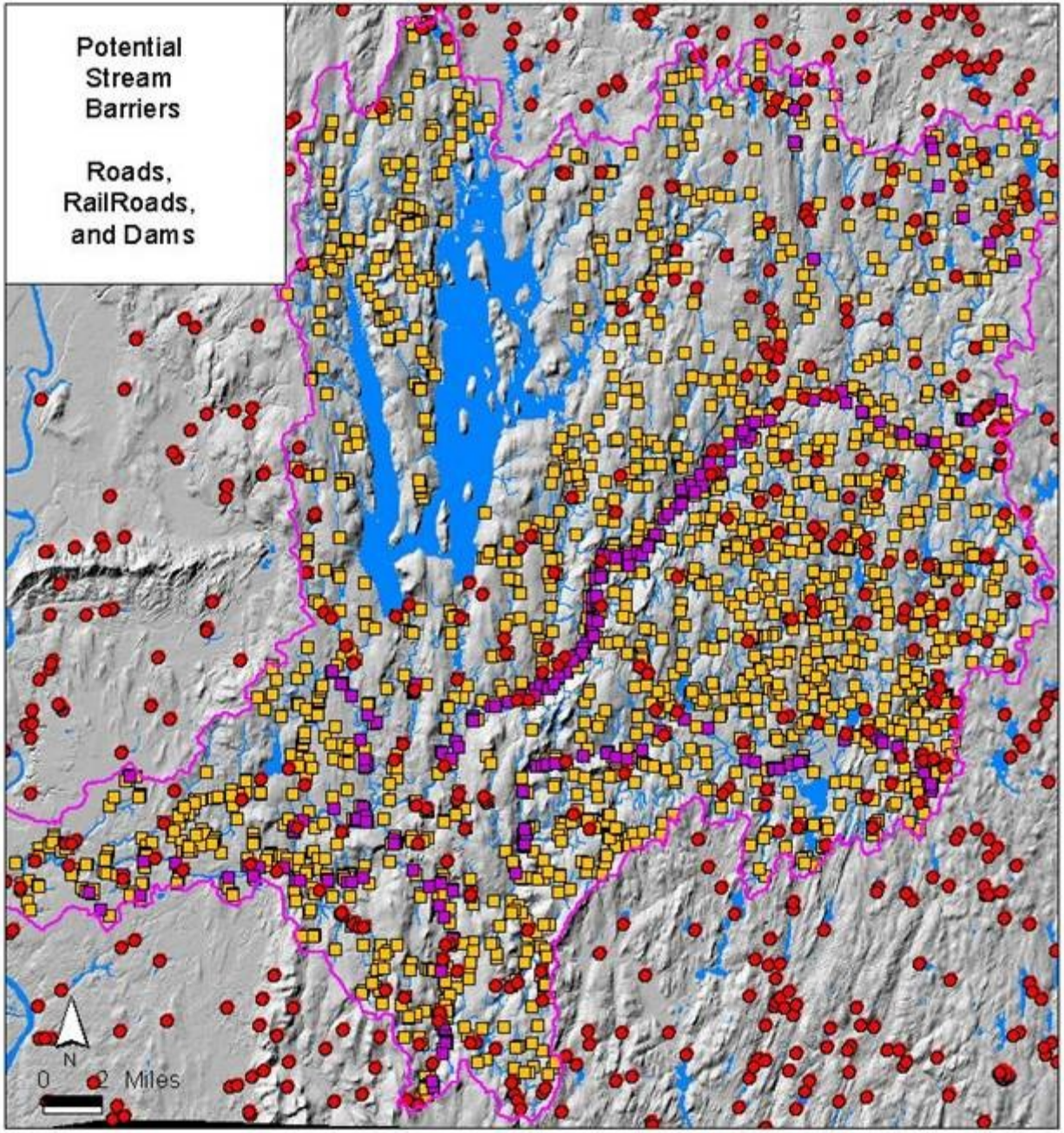
Source:
MA Riverways
Program

CHICOPEE WATERSHED



Source:
MA Riverways
Program

CHICOPEE WATERSHED



Source:
MA Riverways
Program

Regulatory Requirements

Federal:

U.S. Army Corps of Engineers, 2007 Nationwide Permit, General Condition 2 - Aquatic Life Movements:

"No activity may substantially disrupt the necessary life cycle movements of those species of aquatic life indigenous to the waterbody, including those species that normally migrate through the area, unless the activity's primary purpose is to impound water. Culverts placed in streams must be installed to maintain low flow conditions."

State:

"A person shall not…prevent the passing of fish in a stream or the outlet or inlet of a natural or artificial pond on a public stream, by means of a rack, screen, weir or other obstruction."

Three Design Approaches

No-Slope:
The design of an oversized culvert in a low risk site can be simplified and built with little risk.

Hydraulic:
A structure with appropriate hydraulic conditions will allow target species to swim through it.

Stream Simulation:
A channel that simulates characteristics of the adjacent natural channel will present no more of a challenge to movement of organisms than the natural channel.

Hydrauli

Kozmo Bates
Kozmo@AquaKoz.com

tream Simulation Culvert

Kozmo Bates
Kozmo@AquaKoz.com

Stream Simulation Bridge

Stream Simulation Open-bottom Box

Stream Simulation Open-Bottom Arch

Kozmo Bates
Kozmo@AquaKoz.com

Standards

- Bridge span preferred (CT, MA, NH)
- Corrugated culverts preferred over smooth (CT)
- Embedment (CT, MA, NH, VT)
- Natural bottom substrate within culvert (CT, MA, NH, VT)
- Width spans channel, at least:
  - 1.2 x bankfull width (CT, MA)
  - Bankfull width (NH)
- Designed to provide water depths and velocities at a variety of flows that are comparable to those found in upstream and downstream natural stream segments (CT, MA, NH, VT)
- Gradient:
  - Match stream slope (CT, NH, VT)
  - < 3% for culverts (CT)
- Alignment (CT, NH, VT)
- Openness ratio $\geq$ 0.25 calculated in meters (CT, MA, NH)

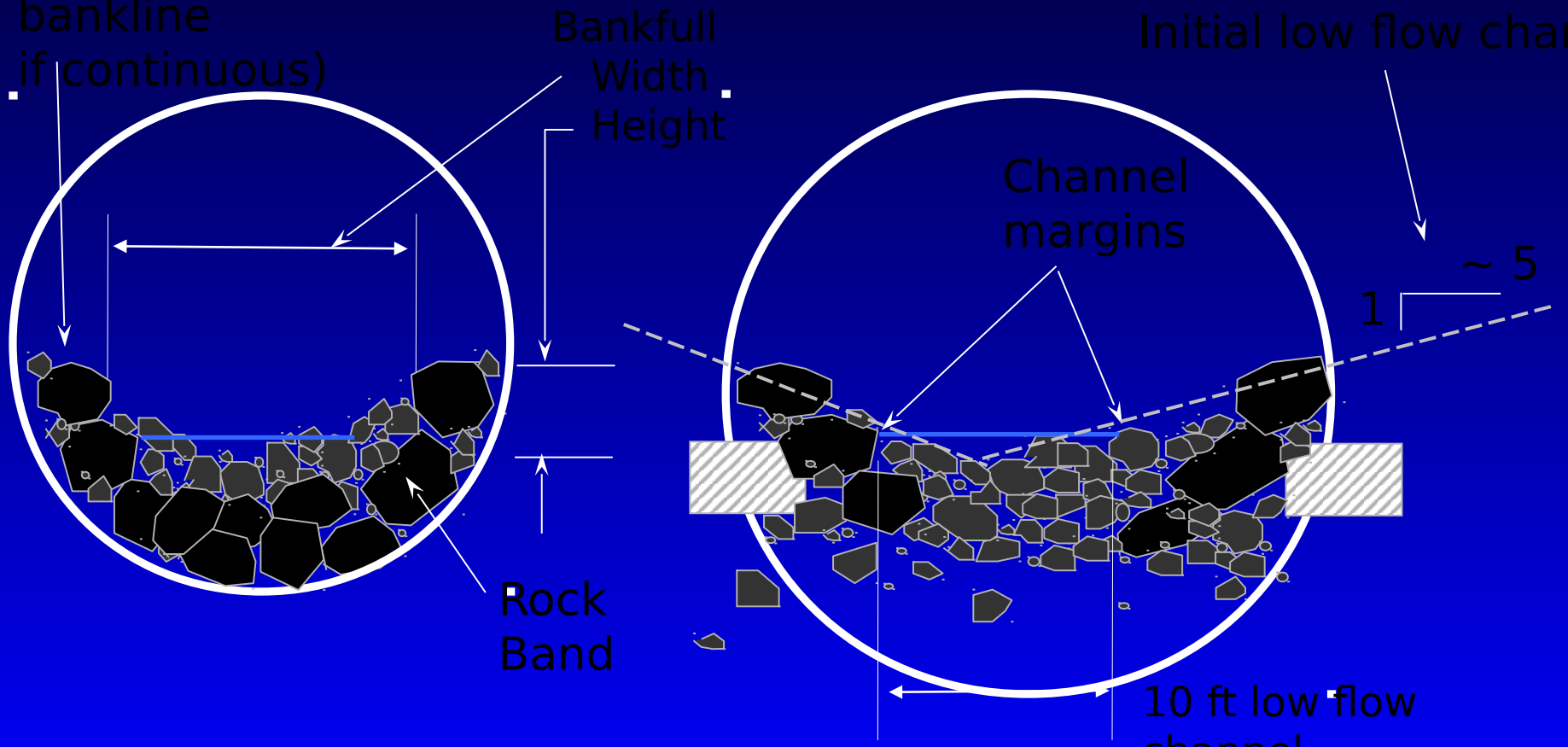
Culvert-able Streams

Stream Width	Culvert Diameter
3’	6’
12’	16’

Margins, Banklines

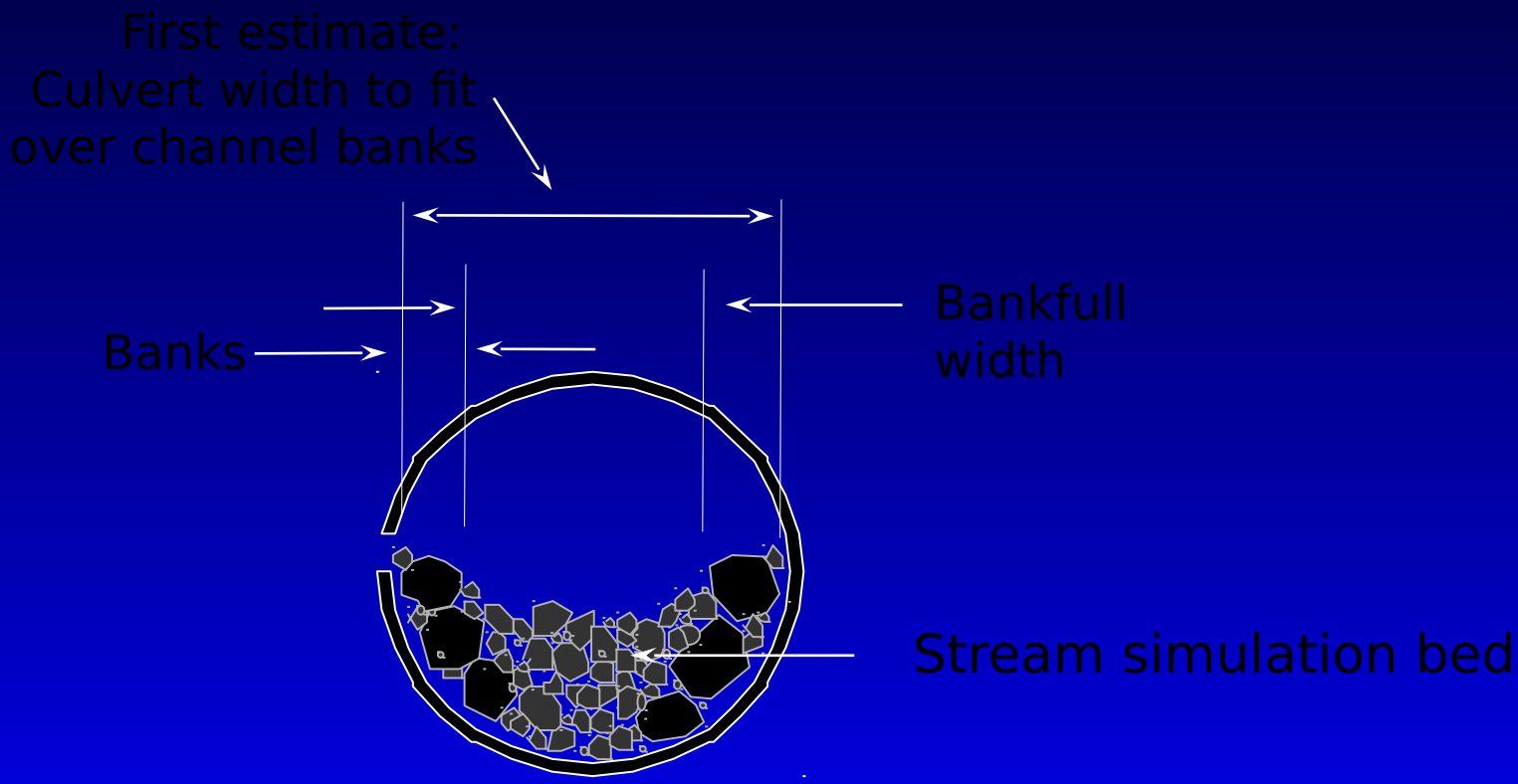
Kozmo Bates,

Stream Simulation Bed
Channel cross-section



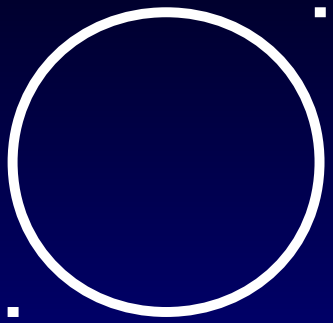
Kozmo Bates,

Stream Simulation
First estimate of culvert width

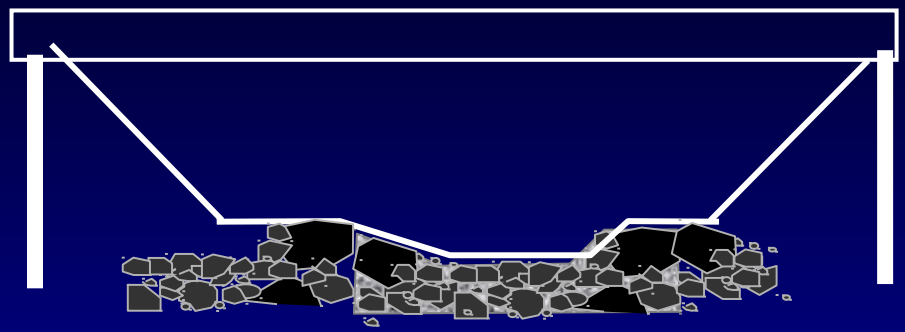


Kozmo Bates,

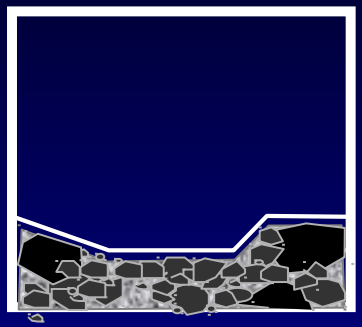
Crossing types



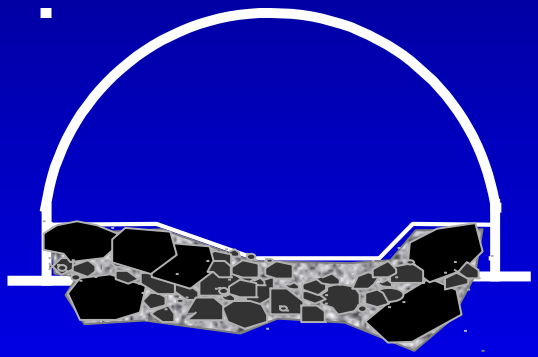
a. Round



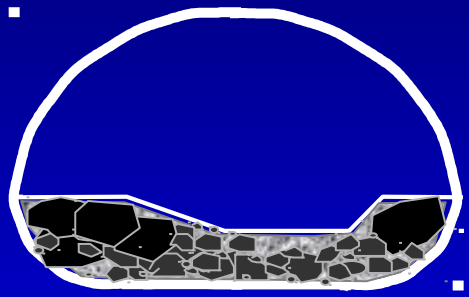
Bridge



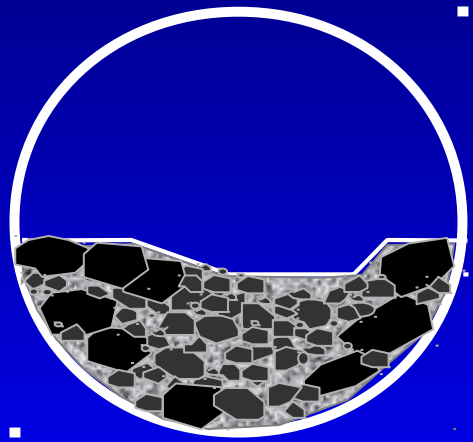
b. Box



d. Bottomless Arch

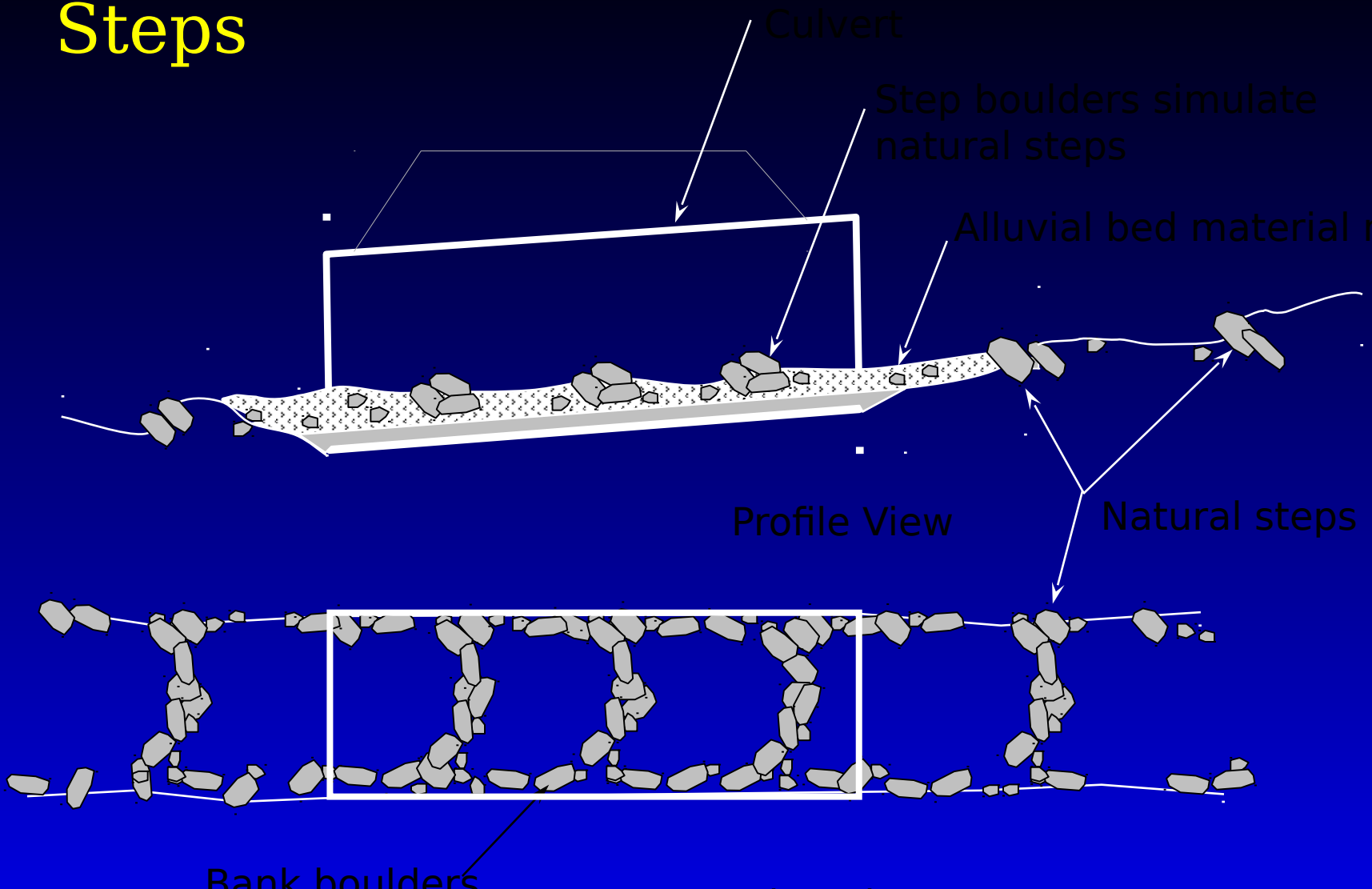


c. Pipe Arch



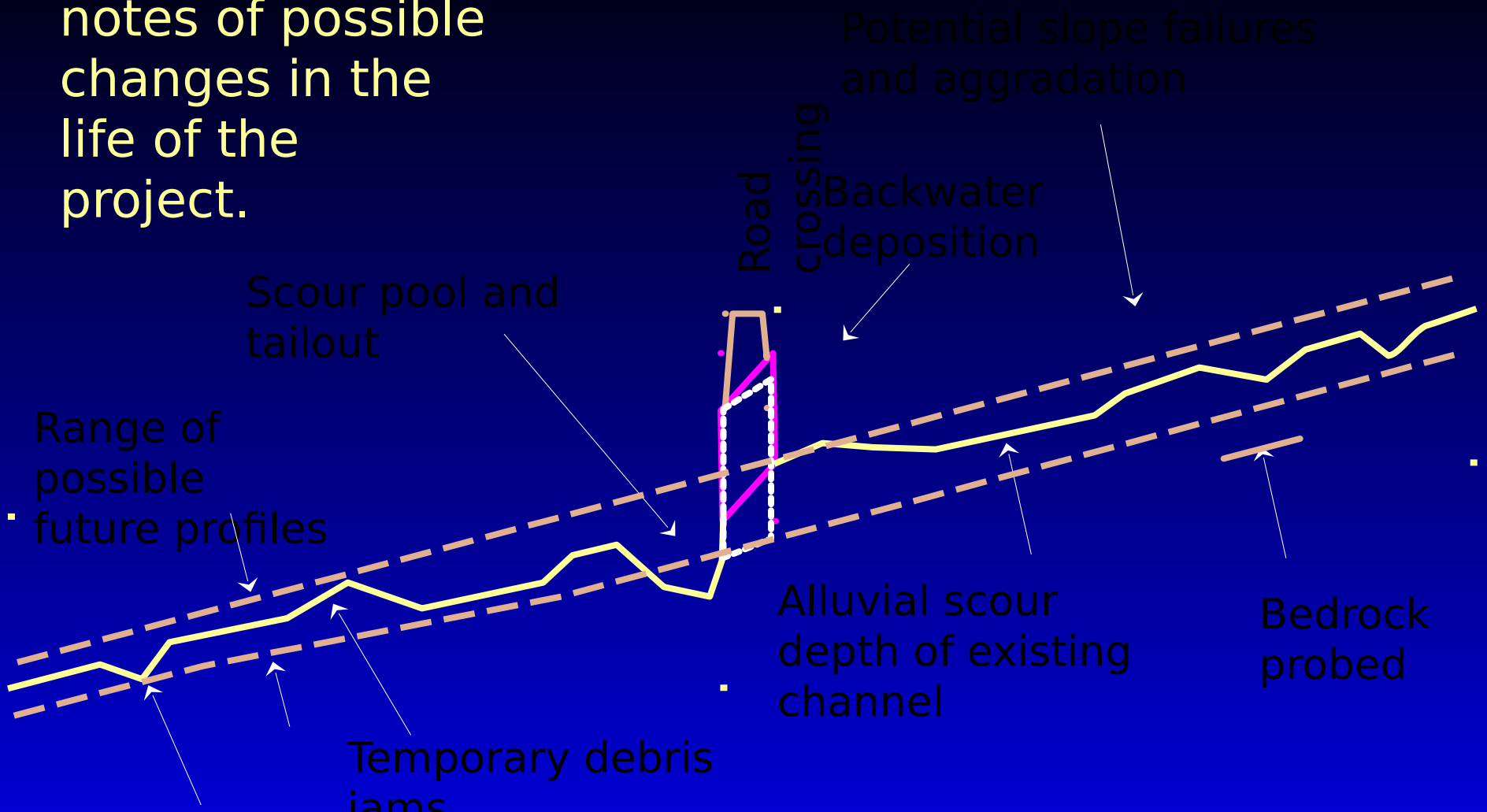
e. Embedded Roun

Steps

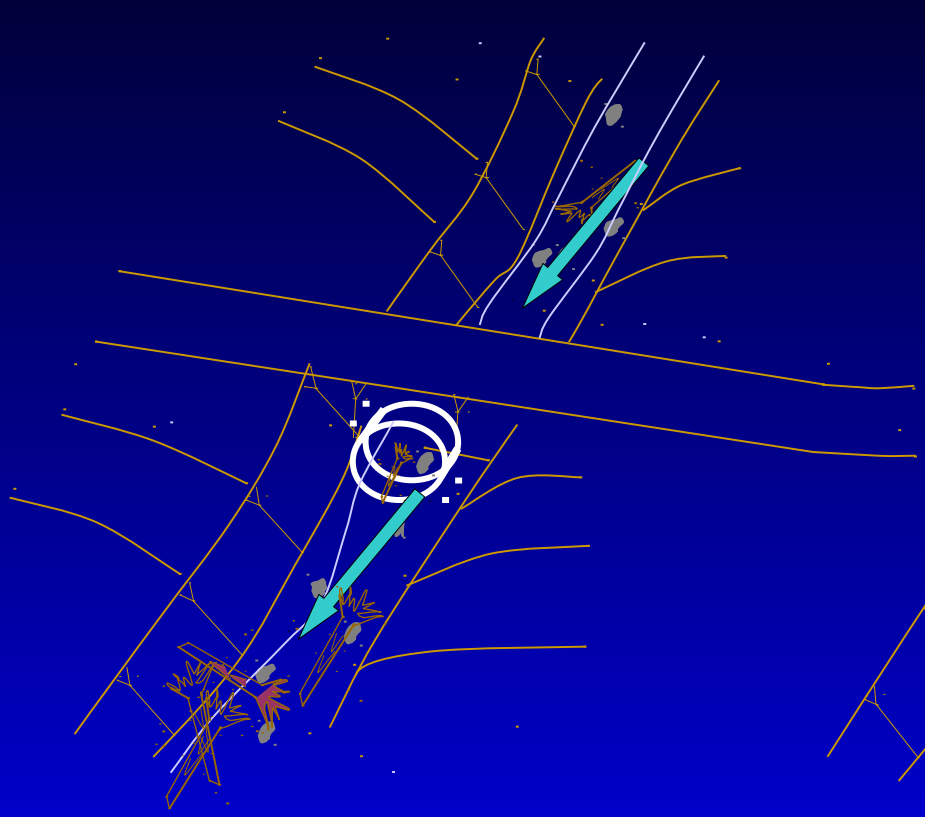


Kozmo Bates,

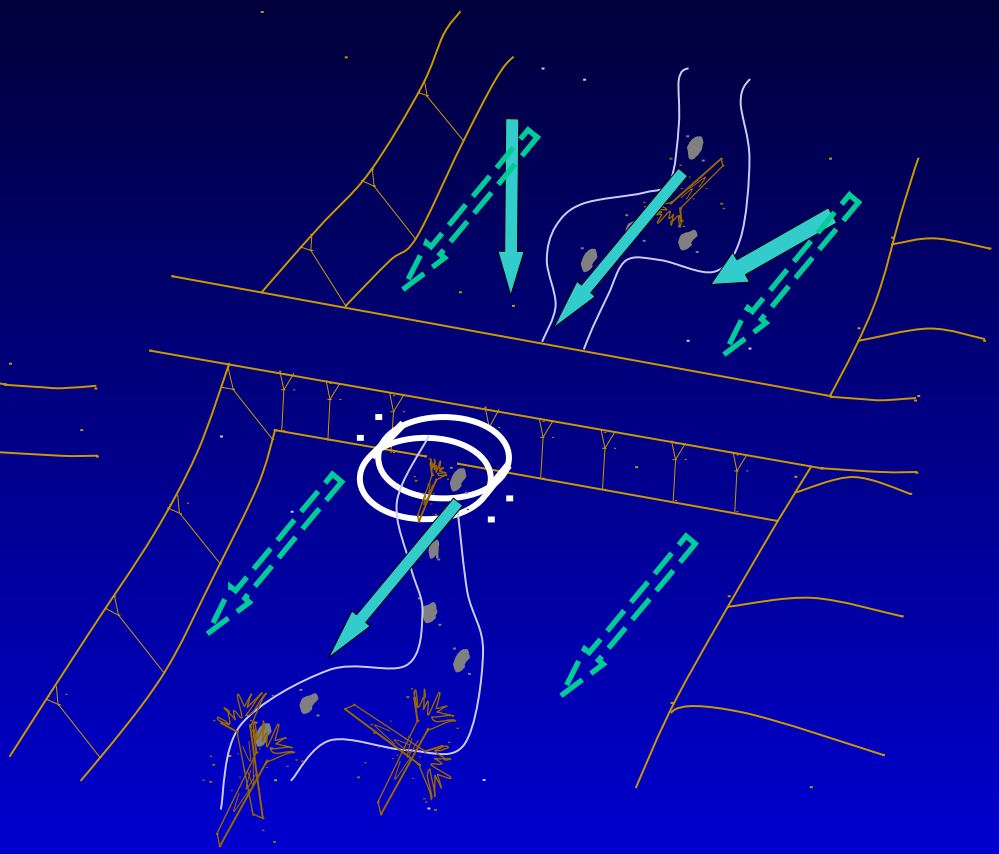
Long profile with notes of possible changes in the life of the project.



Kozmo Bates,



Confined



Unconfined

Kozmo Bates,

Embedment

- **If a culvert then embedded ≥ 2 foot;**
- **≥ 1 foot and 25% for corrugated round culverts**

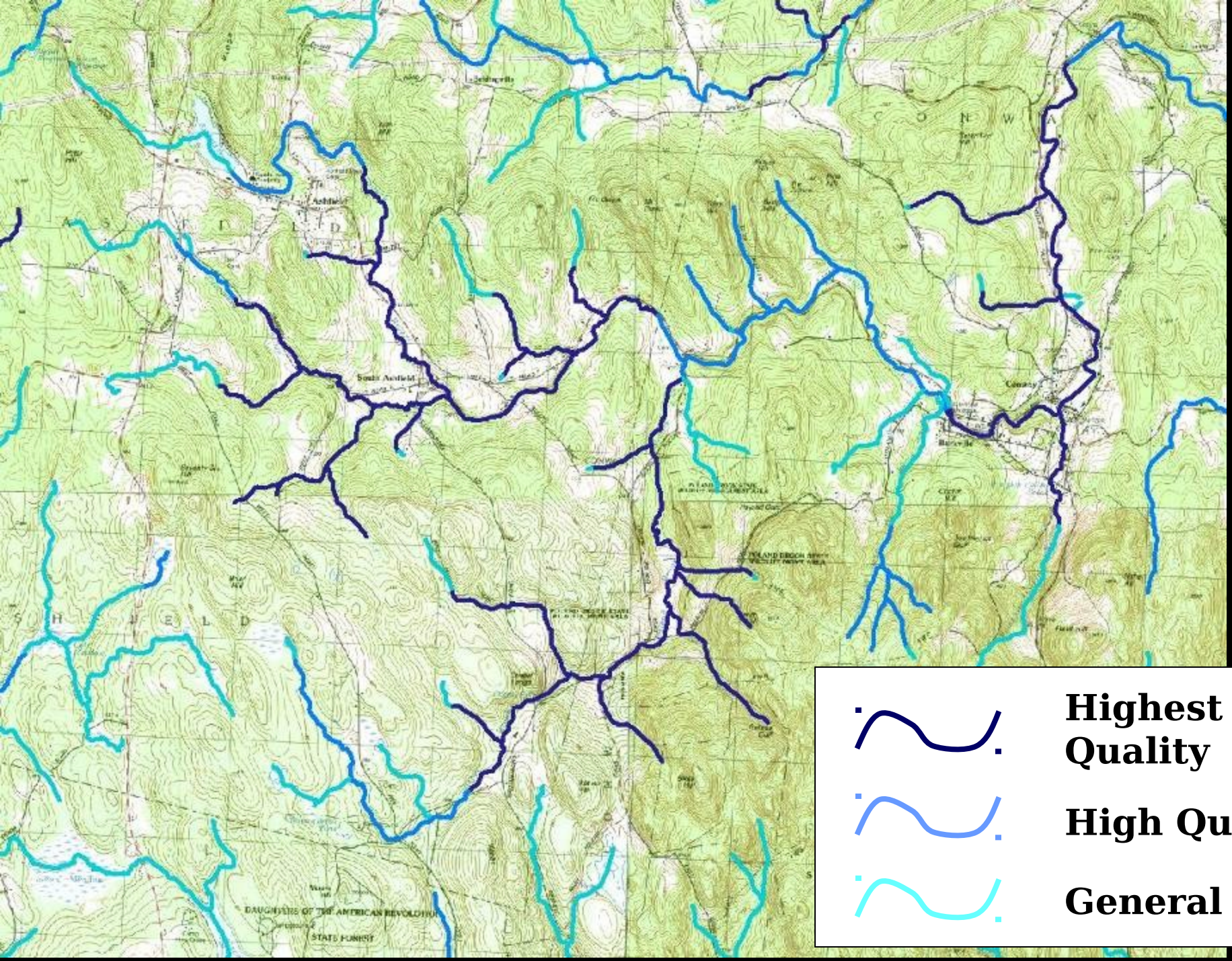
Crossing-Stream Alignment

Johansen

Openness

Ecosystem Restoration Via Crossing Upgrades

- Systematic evaluation of river and stream crossings
- Evaluation of habitat quality and landscape considerations
- Establish priorities for upgrades
- Careful design and construction
- Permitting


Highest Quality
High Quali
General

Assessment Field Forms

6/30/05

Field Data Form: Road-Stream Crossing Inventory

Coordinator	Crossing ID#

Date:_____ Stream/River:_____ Road:_____ Town:_____

Location:_____ GPS Coordinates (lat/long):_____

Observer:_____ Phone #: _____ Email address:_____

Photo IDs: _____

Road/Railway Characteristics

1. # of Travel Lanes:____ Shoulder/ Breakdown lanes: ☐Yes ☐No Road Surface: ☐Paved ☐Unpaved ☐RR
2. Are any of the following conditions present that would significantly inhibit wildlife crossing over the road?

High traffic volume (> 60 cars per minute)	☐ Yes	☐ No
Steep embankments	☐ Yes	☐ No
Retaining walls	☐ Yes	☐ No
Jersey barriers	☐ Yes	☐ No
Fencing	☐ Yes	☐ No

Other (specify) _____

Crossing/Stream Characteristics (during generally low-flow conditions)

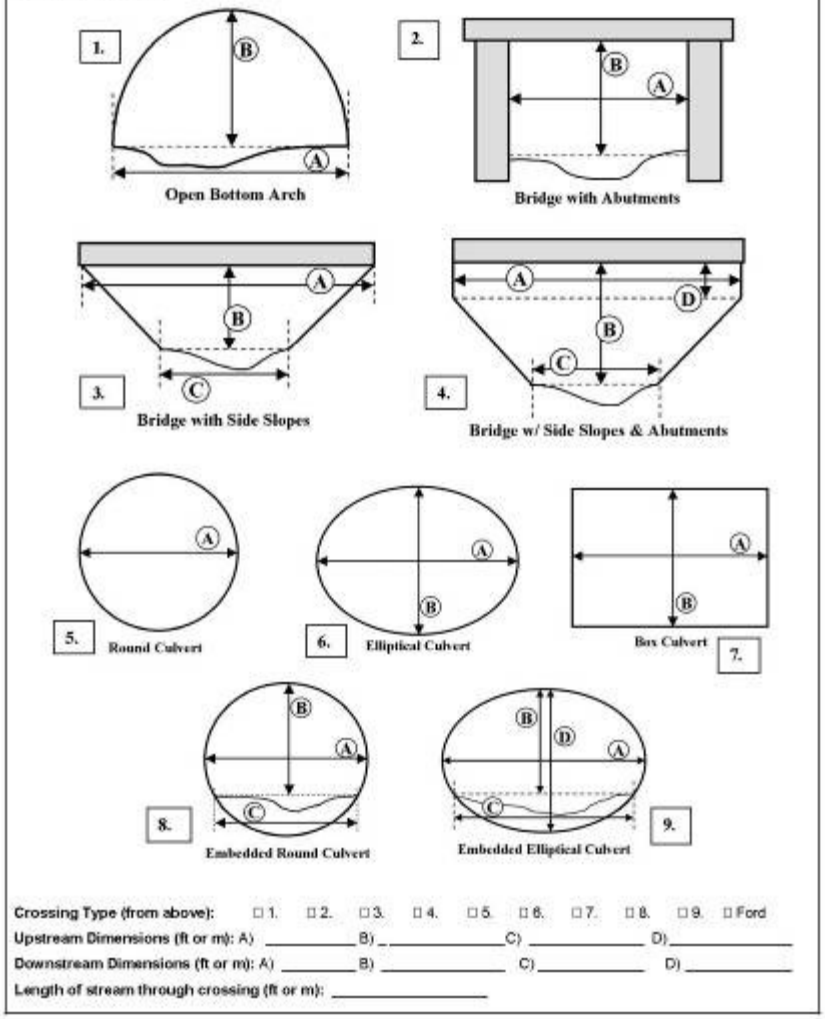
3. Crossing Type: ☐ Ford ☐ Bridge ☐ Open Bottom Arch ☐ Single Culvert ☐ Multiple culverts (# of culverts)_____
4. Condition of crossing: ☐ Good ☐ Fair ☐ Collapsing ☐ Eroding ☐ Rusted through ☐ Broken
5. Does the stream at the crossing contain fish? ☐ Yes ☐ No ☐ Don't know
6. Is the stream flowing (in the natural channel)? ☐ Yes ☐ No
7. Flow conditions during the survey are:
   ☐ unusually low ☐ typical low-flow ☐ average flow ☐ higher than average
8. Are any of the following problems present?

Inlet drop	☐ No	☐ <6"	☐ ≥ 6"
Outlet perch	☐ No	☐ <6"	☐ ≥ 6"
Flow contraction	☐ Yes	☐ No	

9. Tailwater armoring: ☐ Extensive ☐ Not Extensive ☐ None
10. Tailwater scour pool: ☐ Large ☐ Small ☐ None
11. Physical barriers to fish and wildlife passage: ☐ Permanent ☐ Temporary ☐ None
    Describe any barriers:_____
12. Crossing Embedded? ☐ Not embedded ☐ Partially embedded ☐ Fully embedded < 1' ☐ Fully embedded > 1'
13. Crossing substrate: ☐ None ☐ Inappropriate (large rip rap, concrete) ☐ Contrasting ☐ Comparable
14. Water depth matches that of the stream? ☐ Yes (comparable) ☐ No (significantly different)
15. Water velocity matches that of the stream? ☐ Yes (comparable) ☐ No (significantly different)
16. Crossing span: ☐ Constricts channel ☐ Spans active channel ☐ Spans bankfull width ☐ Spans channel & banks
17. Minimum structure height at low water (from water level to the roof inside the structure) ☐ > 6 ft. ☐ 4-6 ft. ☐ < 4 ft.
18. Comments_____

6/30/05

Crossing Dimensions



Crossing Type (from above): ☐ 1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐ Ford

Upstream Dimensions (ft or m): A) _____ B) _____ C) _____ D)_____

Downstream Dimensions (ft or m): A) _____ B) _____ C)_____ D) _____

Length of stream through crossing (ft or m): _____

http://www.streamcontinuity.org - Road Stream Crossing Inventory - Microsoft Internet Explorer
File Edit View Favorites Tools Help Links

NEW ENGLAND ROAD STREAM CROSSING
Inventory Database

Home

Please click on the map or on the link below to select your state:

Massachusetts | Vermont | New Hampshire | Connecticut | Rhode Island | Maine

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http://www.streamcontinuity.org - Road Stream Crossing Inventory - Microsoft Internet Explorer
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Field Data Form: Road-Stream Crossing Inventory

Coordinator: -- **Crossing ID:**

Date: / / **Stream:** **ID:** **Road:**

Town: -- **Location:** **GPS Coord:** Lat: Long:

Observer(s): -- Add Observer(s)

Road/Railway Characteristics:

1. **Number of Travel Lanes:** **Shoulder/ Breakdown lanes:** Yes No **Road Surface:** --
2. **Are any of the following conditions present that would significantly inhibit wildlife crossing over the road?**
   - High traffic volume (> 50 cars per minute) Yes No
   - Steep embankments Yes No
   - Retaining walls Yes No
   - Jersey barriers Yes No
   - Fencing Yes No
   - Other (specify):

Crossing/Stream Characteristics (during generally low-flow conditions)

3. **Crossing Type:** --
4. **Condition of crossing:** -- Describe conditions:
5. **Does the stream at the crossing contain fish?** Yes No Don't know
6. **Is the stream flowing (in the natural channel)?** Yes No
7. **Flow conditions during the survey are:** --
8. **Are any of the following problems present?**
   - Inlet drop No (<6") (>6")
   - Outlet perch No (<6") (>6")
   - Flow contraction Yes No
9. **Tailwater armoring:** --

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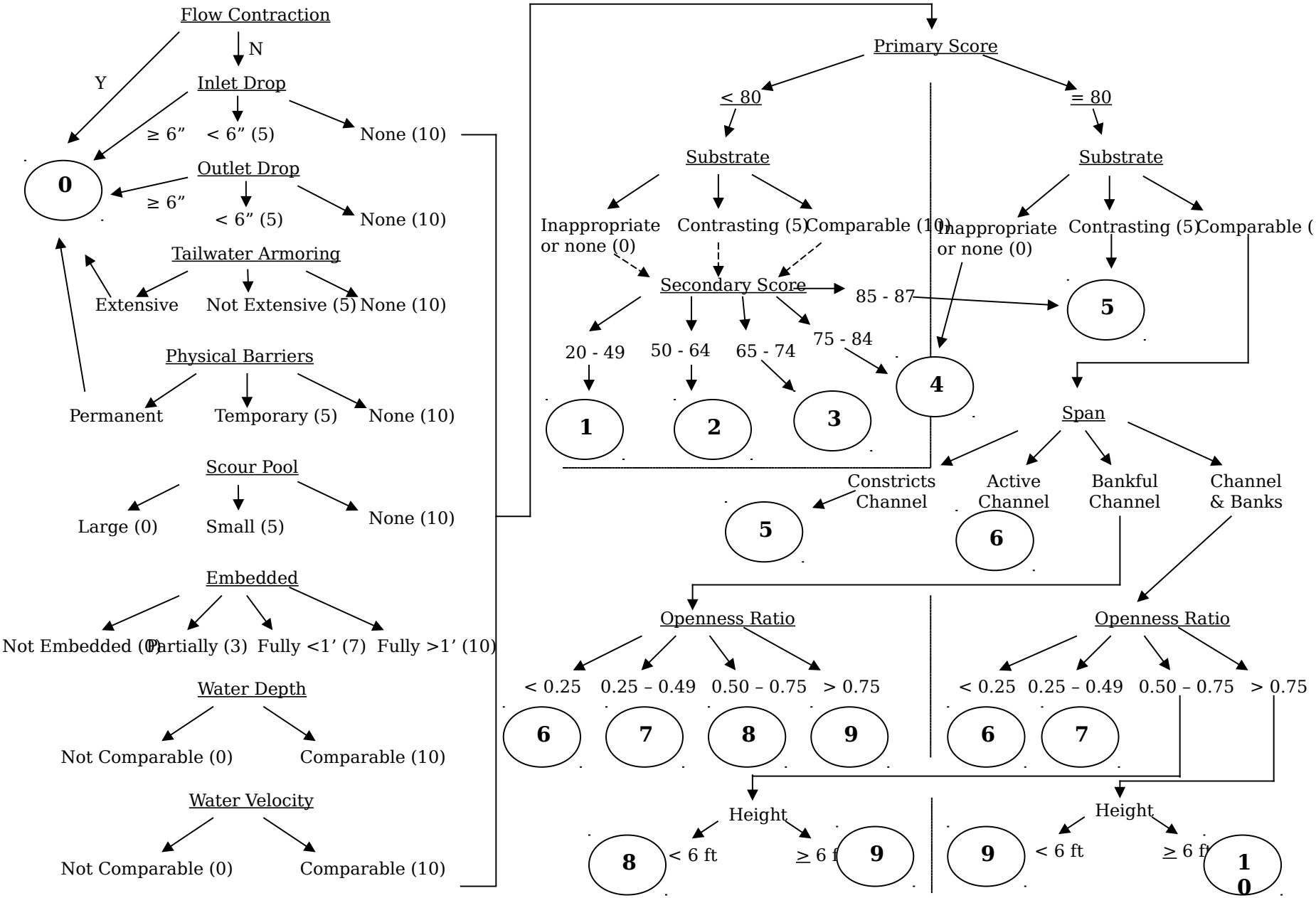
MA Crossing Structures Scoring System



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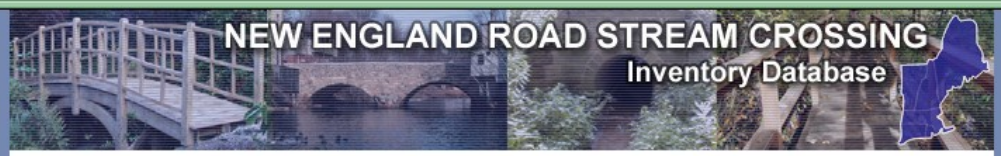

List of Road Stream Crossings:

Get This Page in Excel

State: -- All **Stream Name:** -- All **Standard:** -- All

Search Show All

SB - Severe Barriers, **MDB** - Moderate Barriers, **MIB** - Minor Barriers, **MGS** - Meets General Standard, **MOS** - Meets Optimal Standard

Next [2643]

ID	Town	Stream	Road	Standard	Culverts	Openness
25875	Raynham MA	Bassett Brook	Pine Street	SB	2	0.013
25717	Raynham MA	Forge River	Gardiner Street	SB	1	0.930
26219	Lakeville MA	Poquoy Brook	Cross St	MDB	1	0.024
25714	Middleborough MA	Otis Pratt Brook	Plymouth Street	SB	1	0.005
21646	Sharon MA	Unknown Steam	Castle Drive	SB	1	0.003
21647	Sharon MA	Unknown Steam	Castle Drive	SB	1	0.005
21643	Sharon MA	Unknown Steam	Penny Brook	SB	1	0.003
21653	Sharon MA	Unknown Steam	Bay Road	SB	2	0.008
010900030202-C-188	Burrillville RI	no name	Court House Ln.	MDB	1	0.001
24170/3	Mansfield MA	Robinson Brook	Perkins Ave	MDB	1	0.033
24170/2	Mansfield MA	Robinson Brook	Central Street	MDB	1	0.010
224170	Mansfield MA	Robinson Brook	Copleland Drive	MDB	1	0.019
24709	Mansfield MA	Wading River	West Street	MDB	1	0.055
24942	Mansfield MA	Robinson Pond/ Wading River	Williams Street	MDB	1	0.014
24941	Mansfield MA	Wading River/Robinson Pond	Williams Street	SB	1	0.523
24916	Mansfield MA	Rumford River	Willow Street	MDB	1	0.015

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http://www.streamcontinuity.org - Road Stream Crossing Inventory - Microsoft Internet Explorer
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Add New Crossing | Update This Crossing | View All Crossings

General Information for Road-Stream Crossing ID: 26219

No images uploaded for this crossing

Coordinator: Alison Bowden **Crossing ID:** 26219

Date: 09-28-2007 **Stream:** Poquoy Brook **StreamID:** 26219 **Road:** Cross St

Town: Lakeville, MA **Location:** Near Rte. 44 **GPS:** Lat: 41.9016 Long: -70.9725

Observer: Jacqueline Schmidt **Phone:** (508) 844-3661 **Email:** u_j1schmidt@umassd.edu

Road/Railway Characteristics:

1. **Number of Travel Lanes:** 2 **Shoulder/ Breakdown lanes:** No **Road Surface:** Paved
2. **Are any of the following conditions present that would significantly inhibit wildlife crossing over the road?**

High traffic volume (> 50 cars per minute) :	No
Steep embankments:	No
Retaining walls:	Yes
Jersey barriers :	No
Fencing:	No
Other (specify):	Guardrail, 1 ft high dirt barrier between roadway and street

Crossing/Stream Characteristics (during generally low-flow conditions)

3. **Crossing type:** Single Culvert
4. **Condition of crossing:** Fair
   Comments:
5. **Does the stream at the crossing contain fish?** Don't know
6. **Is the stream flowing (in the natural channel)?** Yes
7. **Flow conditions during the survey are:** Unusually low
8. **Are any of the following problems present? (see attached glossary and illustrations)**

Inlet drop:	No
Outlet perch:	No
Flow contraction:	No

9. **Tailwater armoring:** Not Extensive
10. **Tailwater scour pool:** None
11. **Physical barriers to fish and wildlife passage:** None

Describe any barriers: N/A

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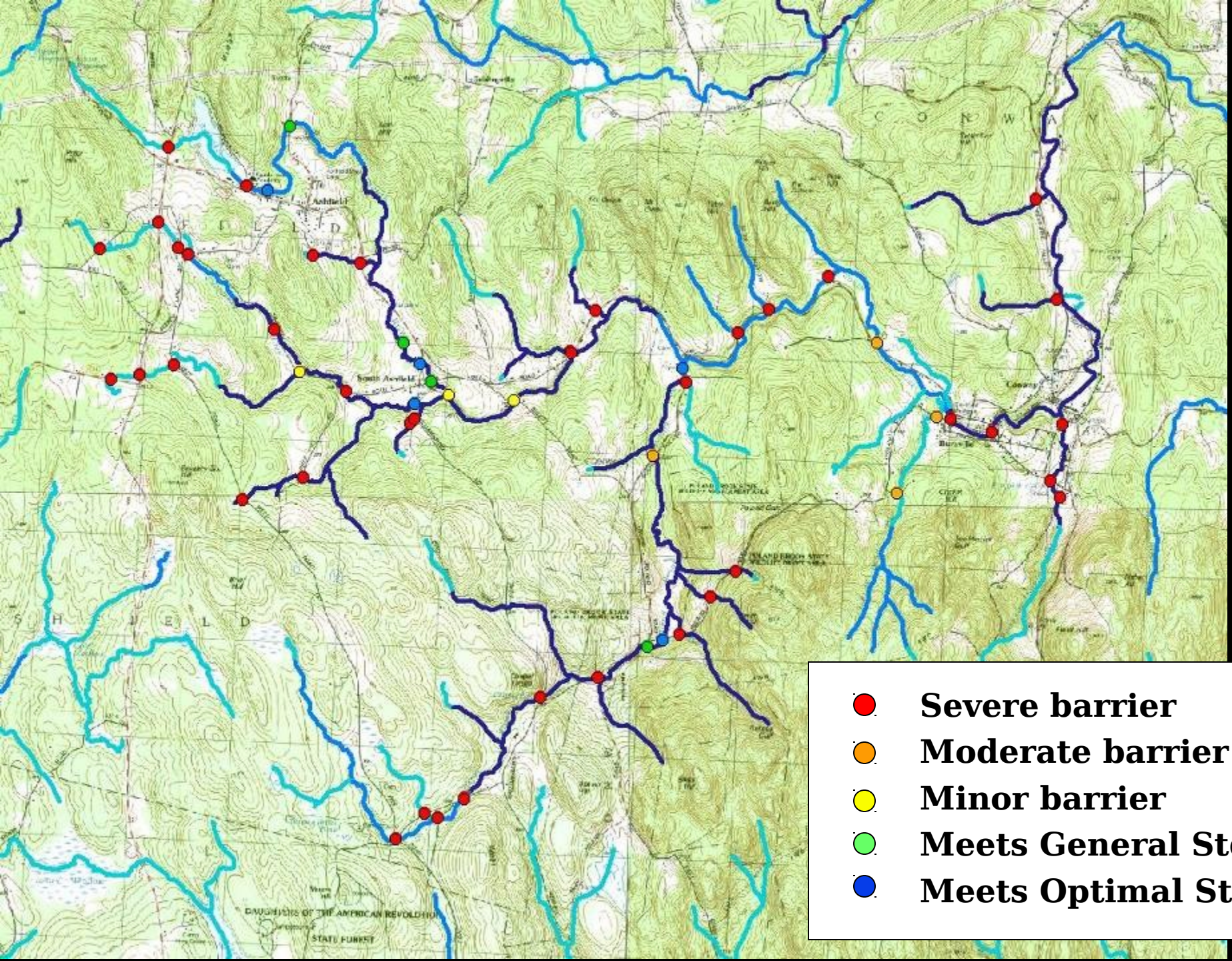
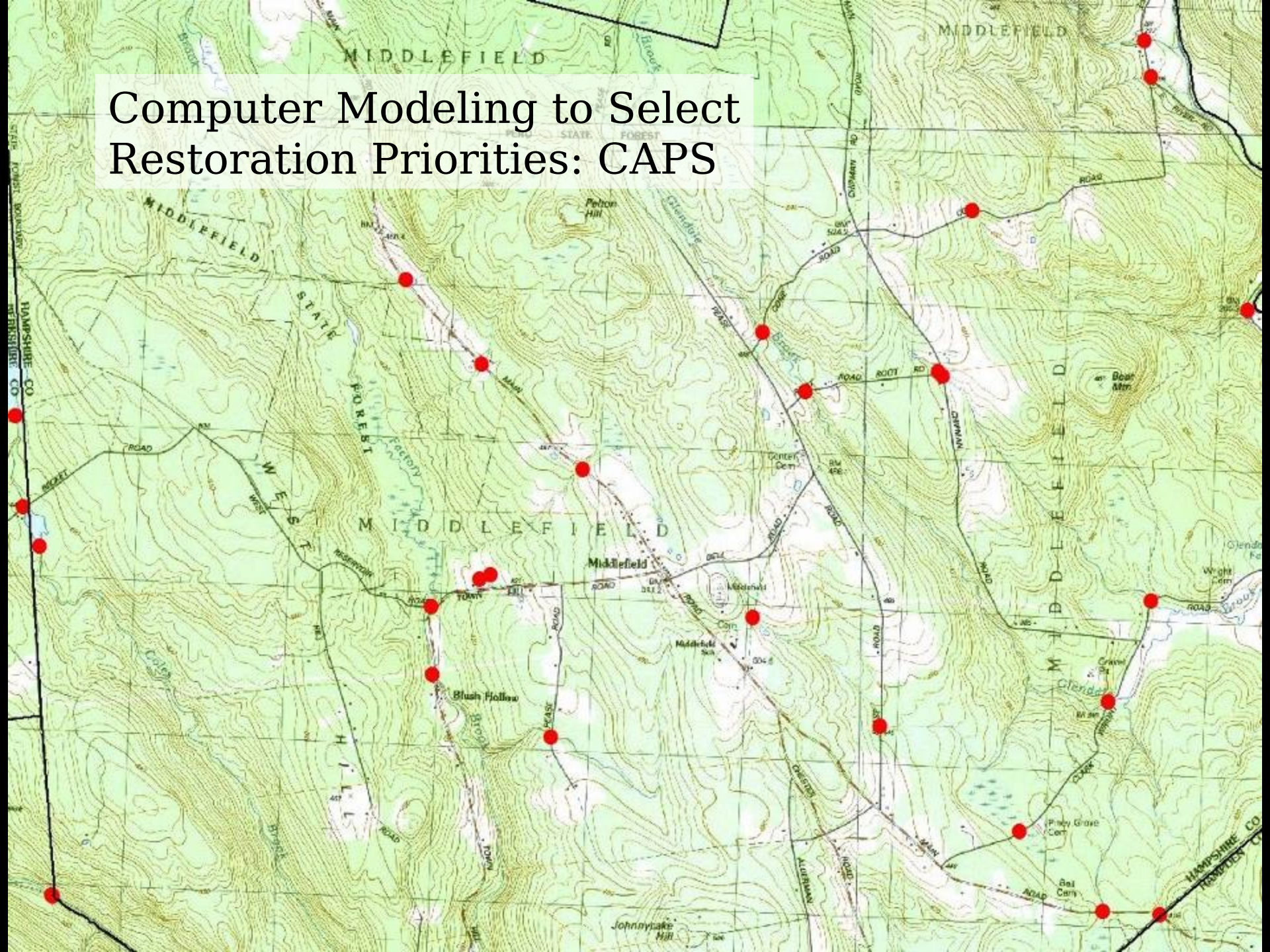

Severe barrier
Moderate barrier
Minor barrier
Meets General Stds
Meets Optimal Stds


Computer Modeling to Select Restoration Priorities: CAPS
MIDDLEFIELD
MIDDLEFIELD
MIDDLEFIELD
WEST
HILL
Middlefield
Blush Hollow
Johnnycake Hill
Pelton Hill
Center Cem.
Bear Mtn.
Wright Cem.
Glendale
Factory Brook
Caldwell Brook
Colby Brook
Brush Brook
Brooks Brook
Cowles Brook
Glendale Brook
Middlefield Sch.
Pkwy Grove Cem.
Bell Cem.
STATE FOREST
HAMPSHIRE CO.
HAMPDEN CO.
MAIN ROAD
ROOT RD.
CRAWMAN ROAD
CENTER ROAD
RIDGE ROAD
RESERVOIR ROAD
ALLERMAN ROAD
FOREST ROAD
TOWN ROAD
BECKET ROAD
WEST ROAD
HILL ROAD
CHAPEL ROAD
CHESTER ROAD
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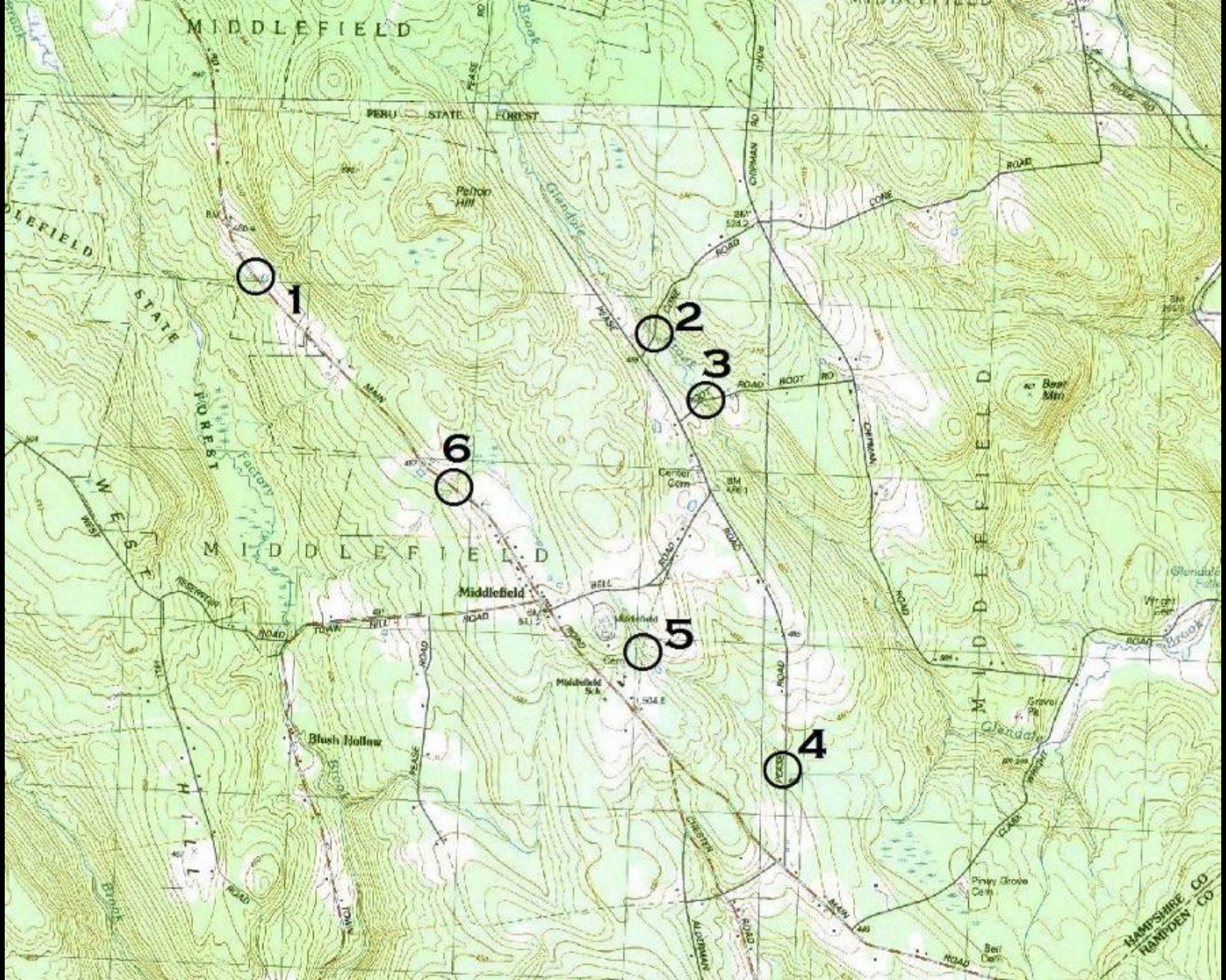
MIDDLEFIELD
PERU STATE FOREST
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Glendale Brook
Chapman Rd
Corse Road
Root Rd
Main
Center Cem
Middlefield
Bell Road
Town Hill Road
Reservoir
Middlefield Sch
Blush Hollow
Brook
Chester
Alderman Road
Clark
Gravel Pit
Piney Grove Cem
Bell Cem
Wright Cem
Glendale Falls
Brook
Factory
West
Hill
Road
Pease
Brook
1
2
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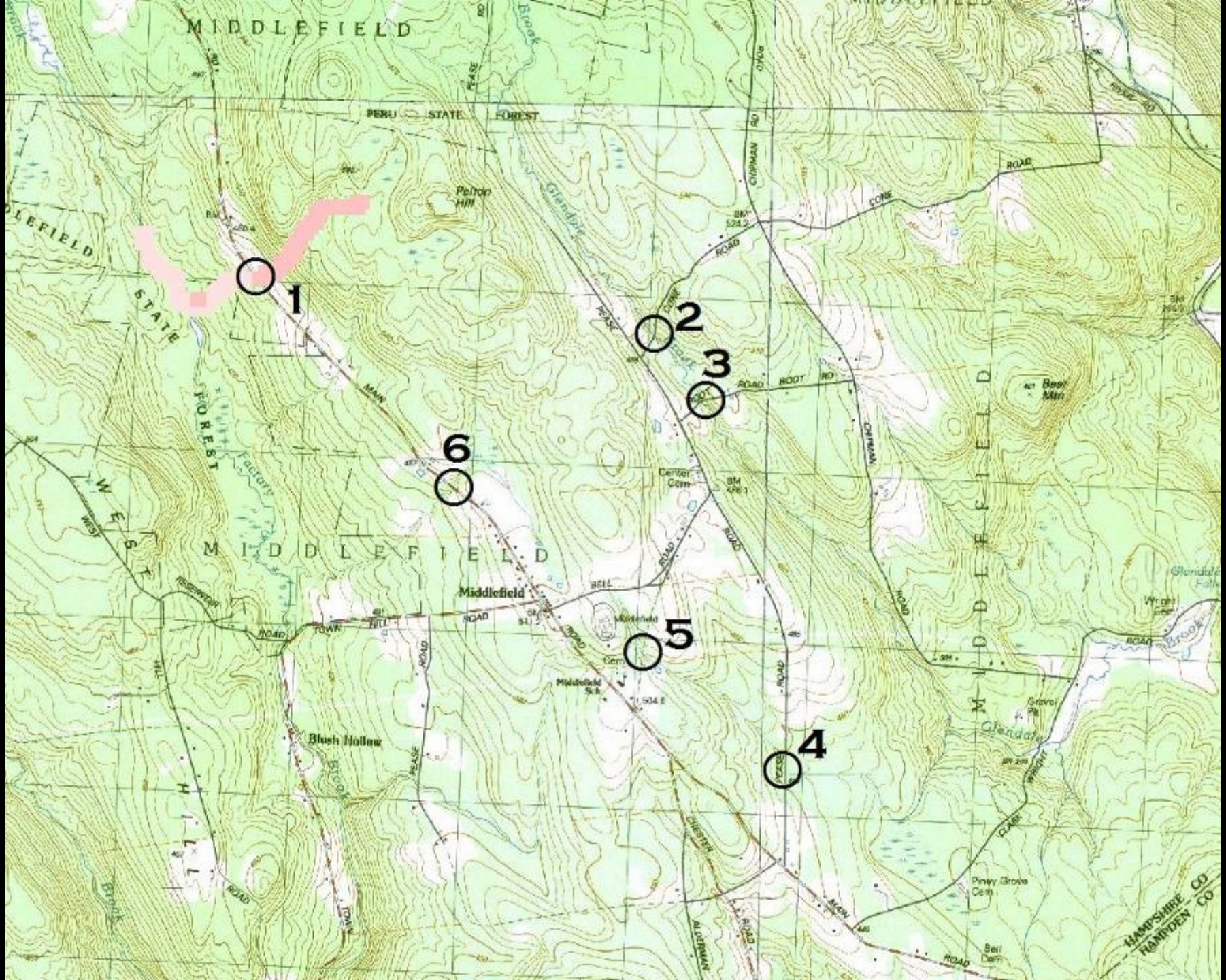
5
6
HAMPSHIRE CO
HAMPDEN CO


MIDDLEFIELD
PERU STATE FOREST
Pease Brook
Peiton Hill
Glendale
CHAPMAN RD
CONE ROAD
ROOT RD
Best Mtn
MIDDLEFIELD STATE FOREST
MAIN
Factory
WEST
HILL
ROAD
Middlefield
Center Cem
BELL
TOWN
Middlefield Sch
Blush Hollow
Brook
CHESTER
ALDERMAN
CLARK
Piney Grove Cem
Bell Cem
HAMPSHIRE CO
HAMPDEN CO
1
2
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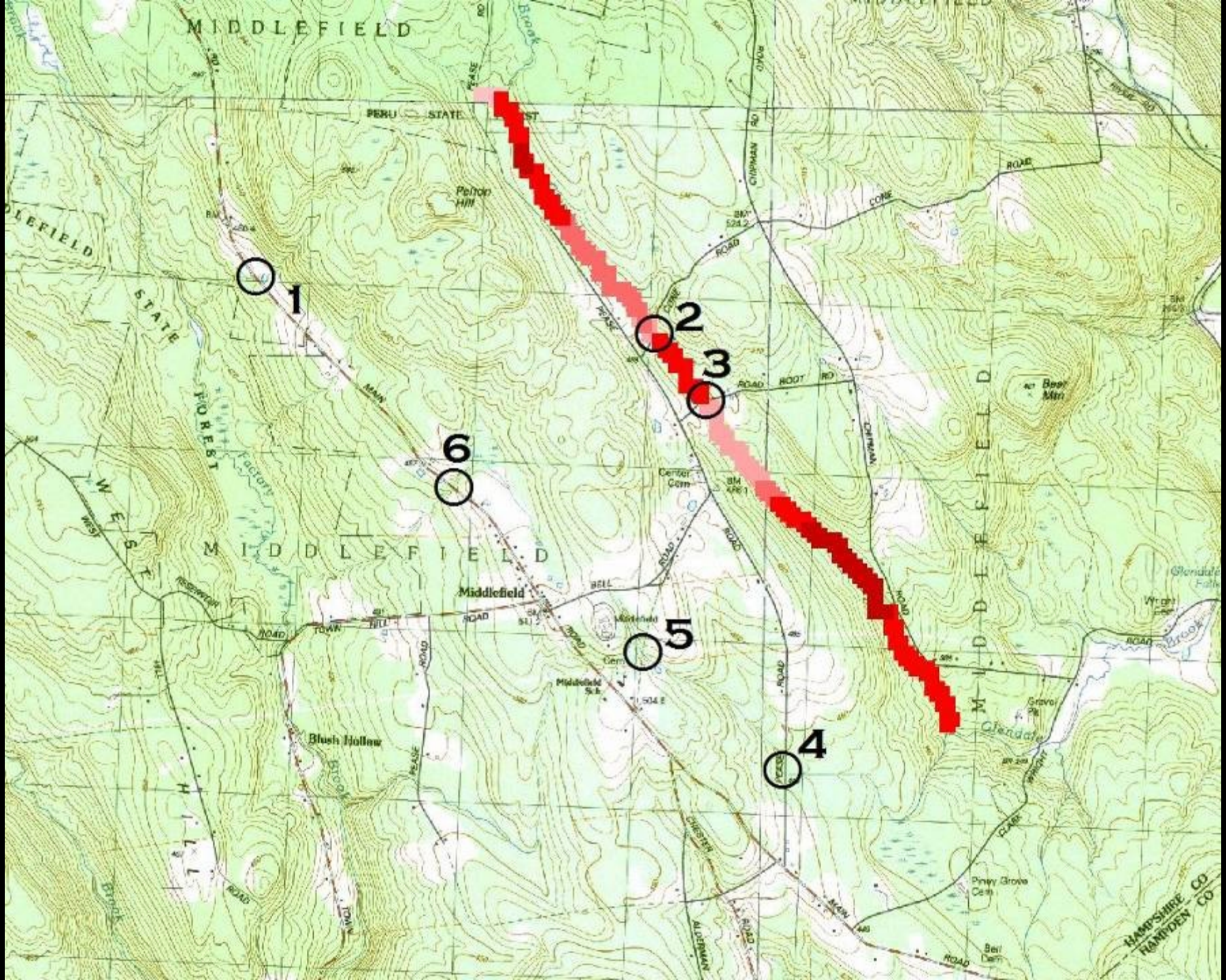
MIDDLEFIELD
PERU STATE FOREST
Pease Brook
Chapman Rd
Corse Road
Pelton Hill
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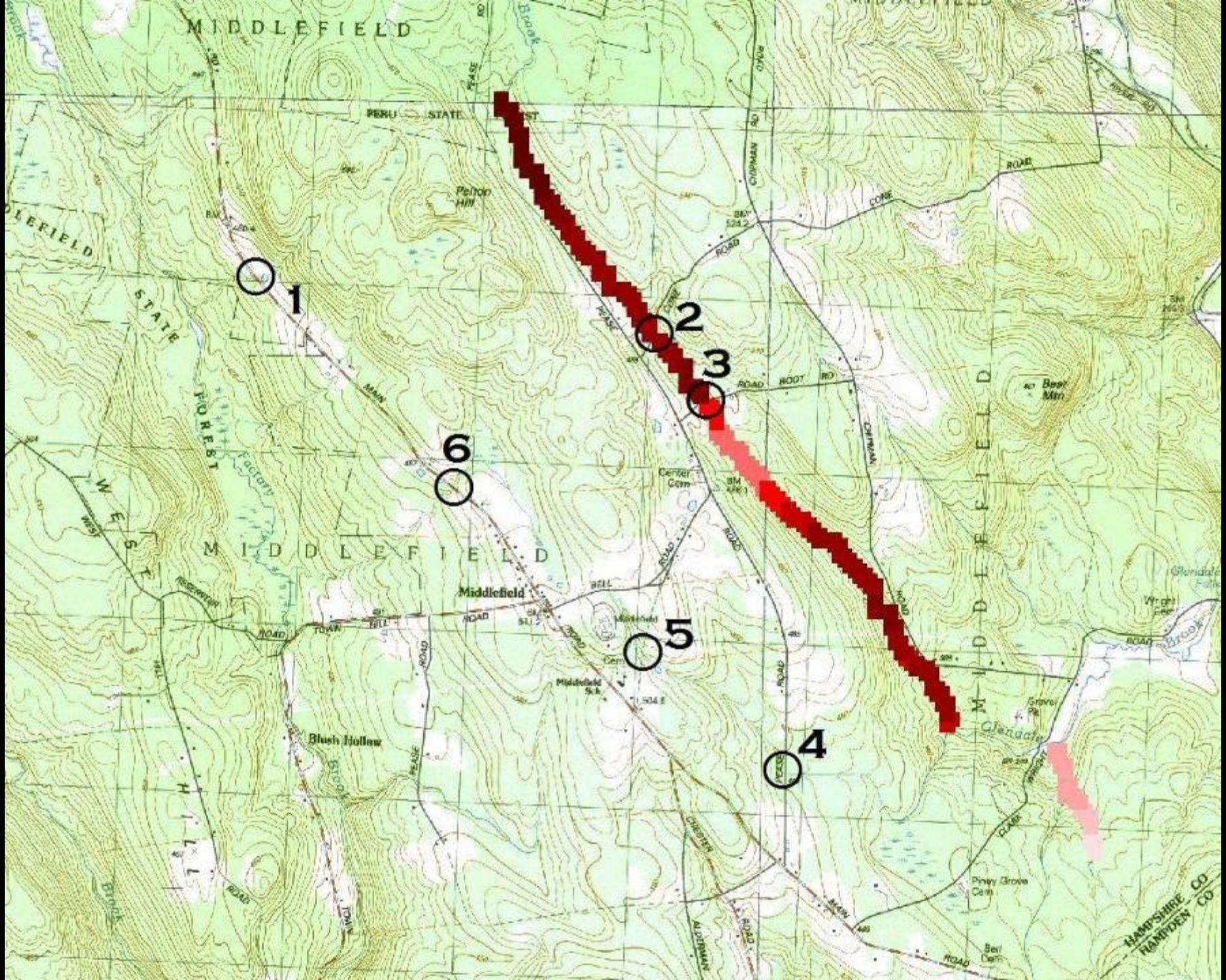
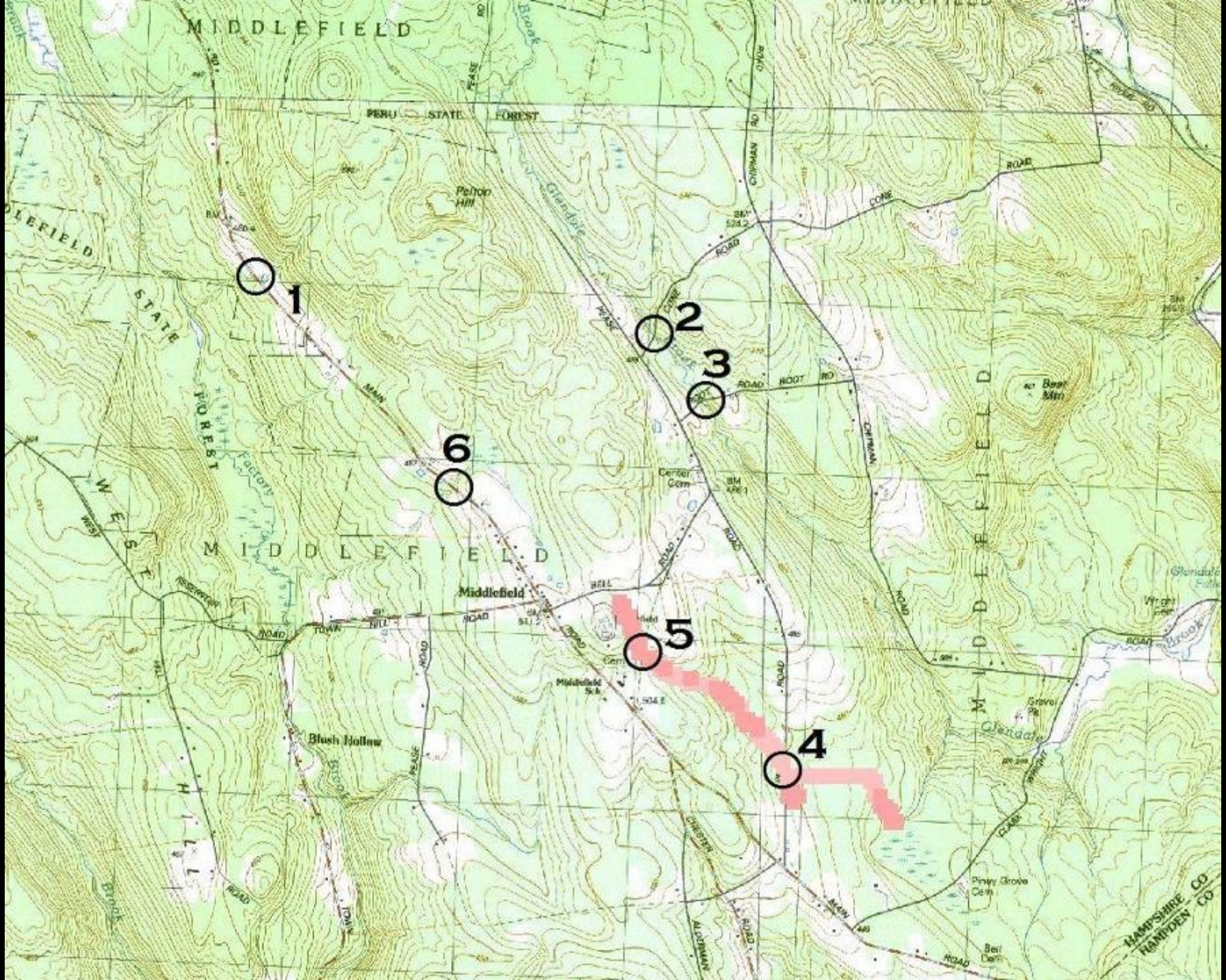
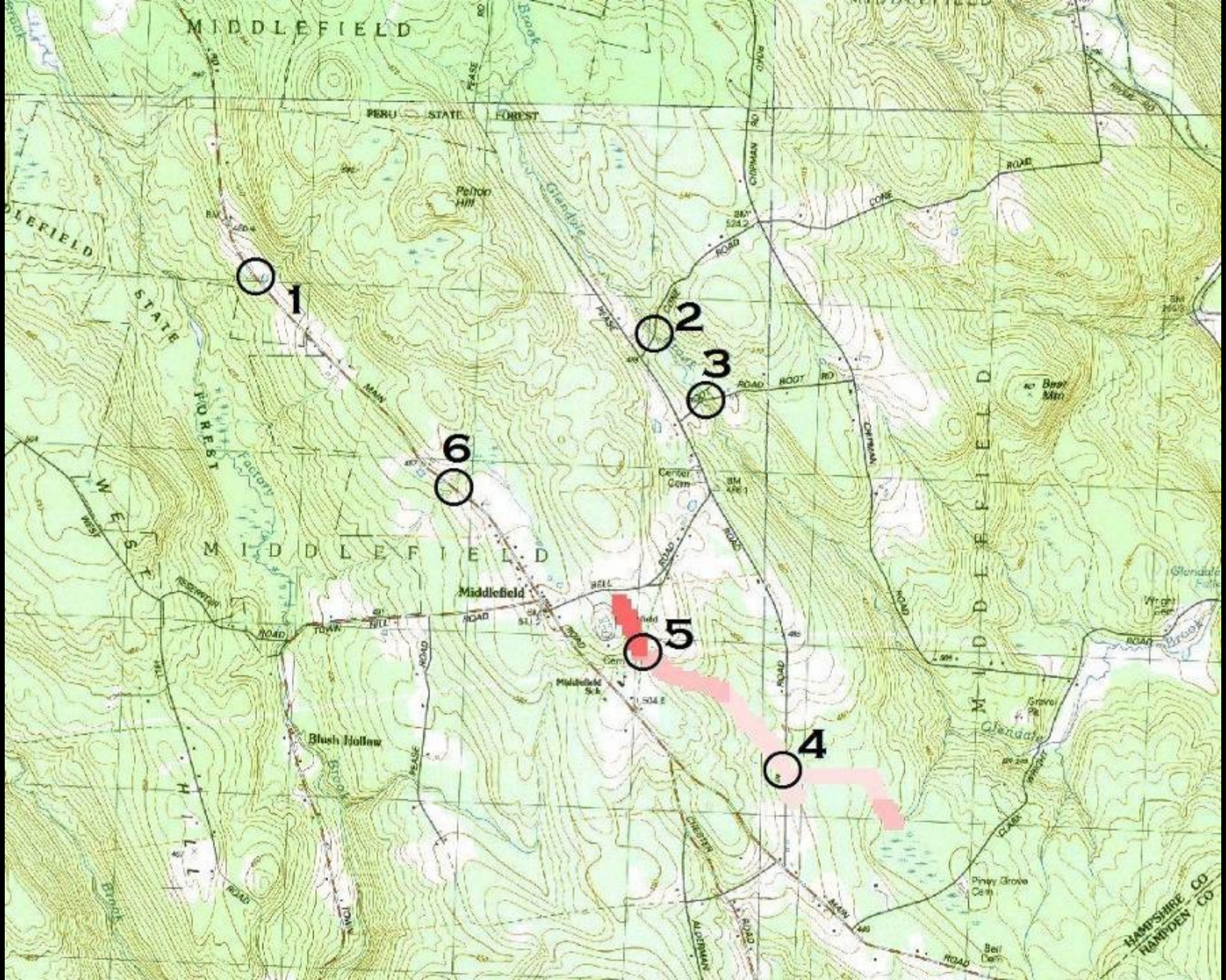
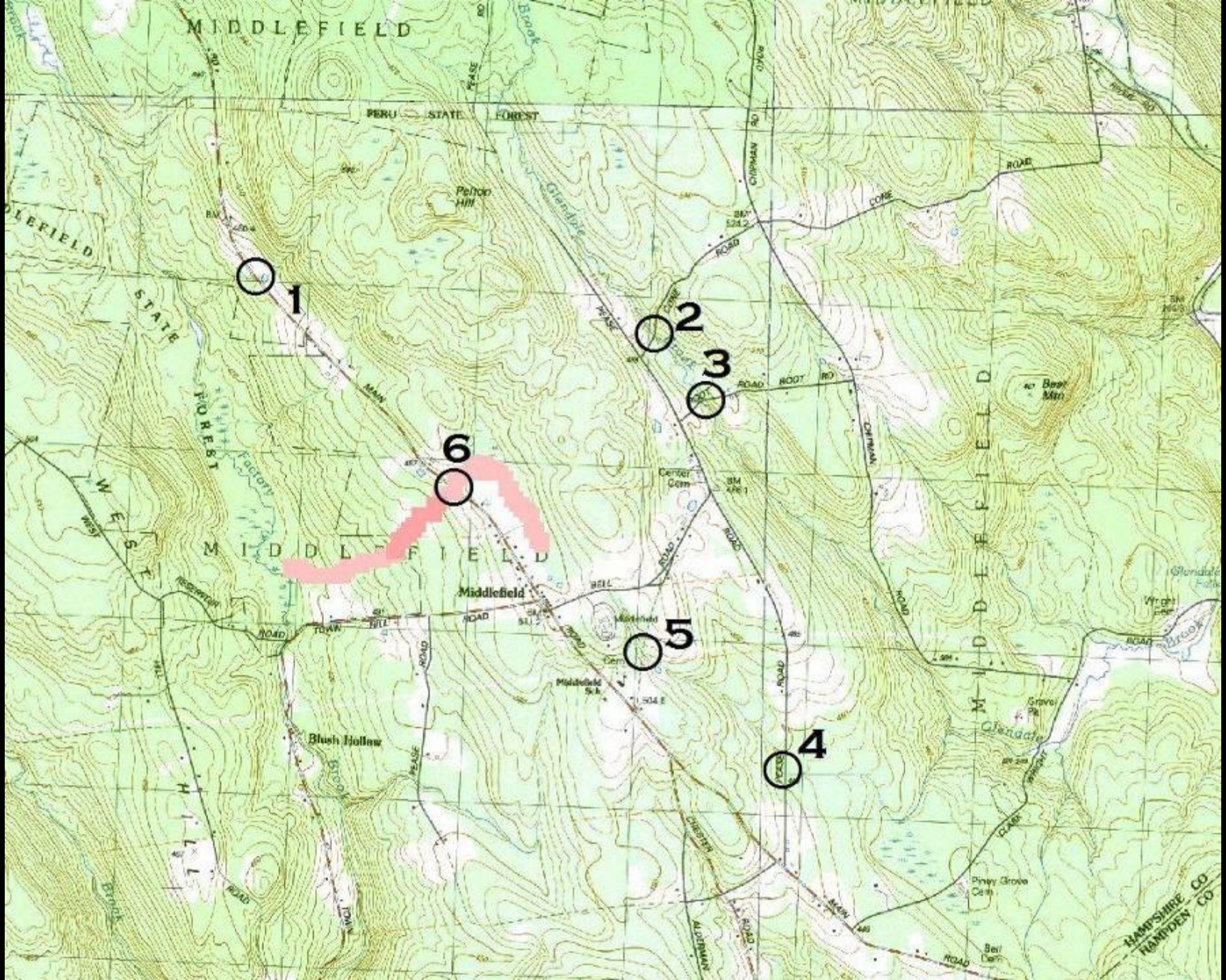
2
3
Root Rd
Best Mtn
Middlefield State Forest
Factory
Main
6
Center Cem
Middlefield
Bell Road
Town Hill Road
Middlefield Sch
5
Blush Hollow
Brook
Chester
Alderman Road
4
Gravel Pit
Glendale
Clark Brook
Piney Grove Cem
Bell Cem
HAMPSHIRE CO
HAMPDEN CO

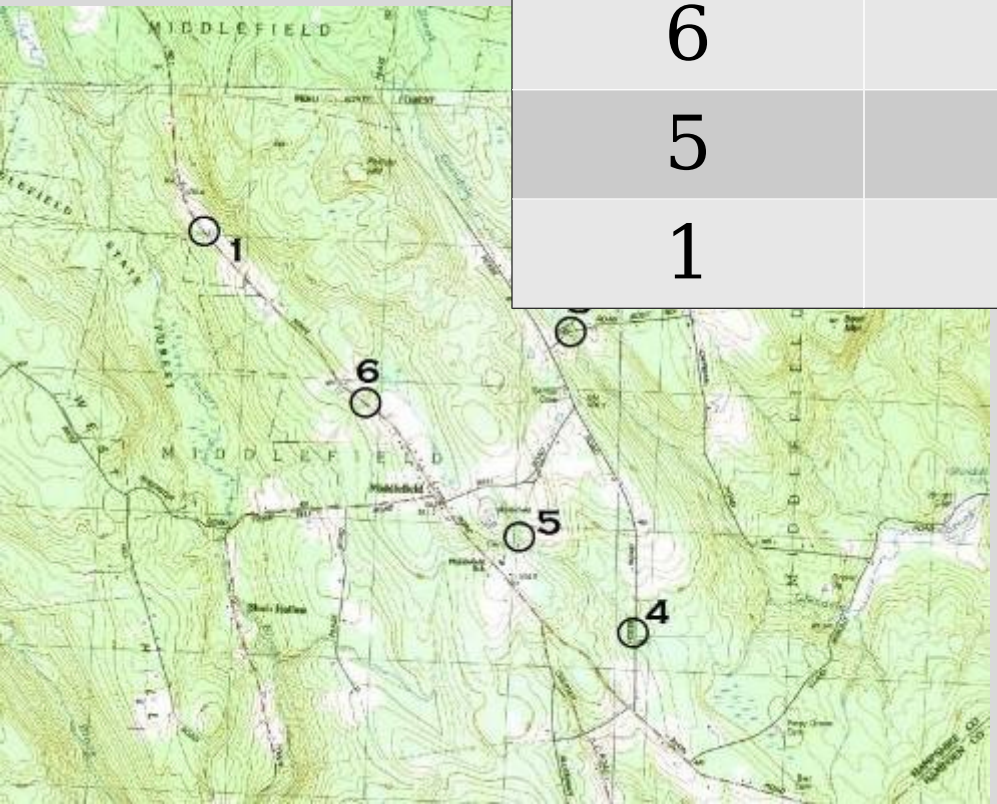

MIDDLEFIELD
PERU STATE FOREST
Pelton Hill
1
2
3
4
5
6
MIDDLEFIELD
Middlefield
Blush Hollow
WEST MIDDLEFIELD HILL
MIDDLEFIELD STATE FOREST
Glendale
HAMPSHIRE CO
HAMPDEN CO


MIDDLEFIELD
PERU STATE FOREST
Pelton Hill
Glendale Brook
Chapman Rd
Corse Road
Root Rd
Main Road
Center Cem
Middlefield
Middlefield Sch
Town Hill Road
Blush Hollow
Blush Hollow Brook
Factory Brook
Glendale Brook
Gravel Pit
Piney Grove Cem
Bell Cem
Alderman Road
Chester Road
Clark Road
Reservoir Road
West Hill Road
Middlefield State Forest
HAMPSHIRE CO
HAMPDEN CO
1
2
3
4
5
6


MIDDLEFIELD
PERU STATE FOREST
Pease Brook
Glendale Brook
Pelton Hill
Chapman Rd
Corse Road
Root Rd
Main Road
Center Cem
Middlefield
Bell Road
Town Hill Road
Reservoir Road
Blush Hollow
Blush Hollow Brook
Factory Brook
Middlefield Sch
Gravel Pit
Piney Grove Cem
Bell Cem
Alderman Road
Clark Road
Chester Road
Wright Corner Road
Glendale Falls
Best Mtn
WEST MIDDLEFIELD STATE FOREST
HILL
HAMPSHIRE CO
HAMPDEN CO
1
2
3
4
5
6


MIDDLEFIELD
PERU STATE FOREST
Pelton Hill
Glendale Brook
Middlefield
Blush Hollow
Brook
1
2
3
4
5
6

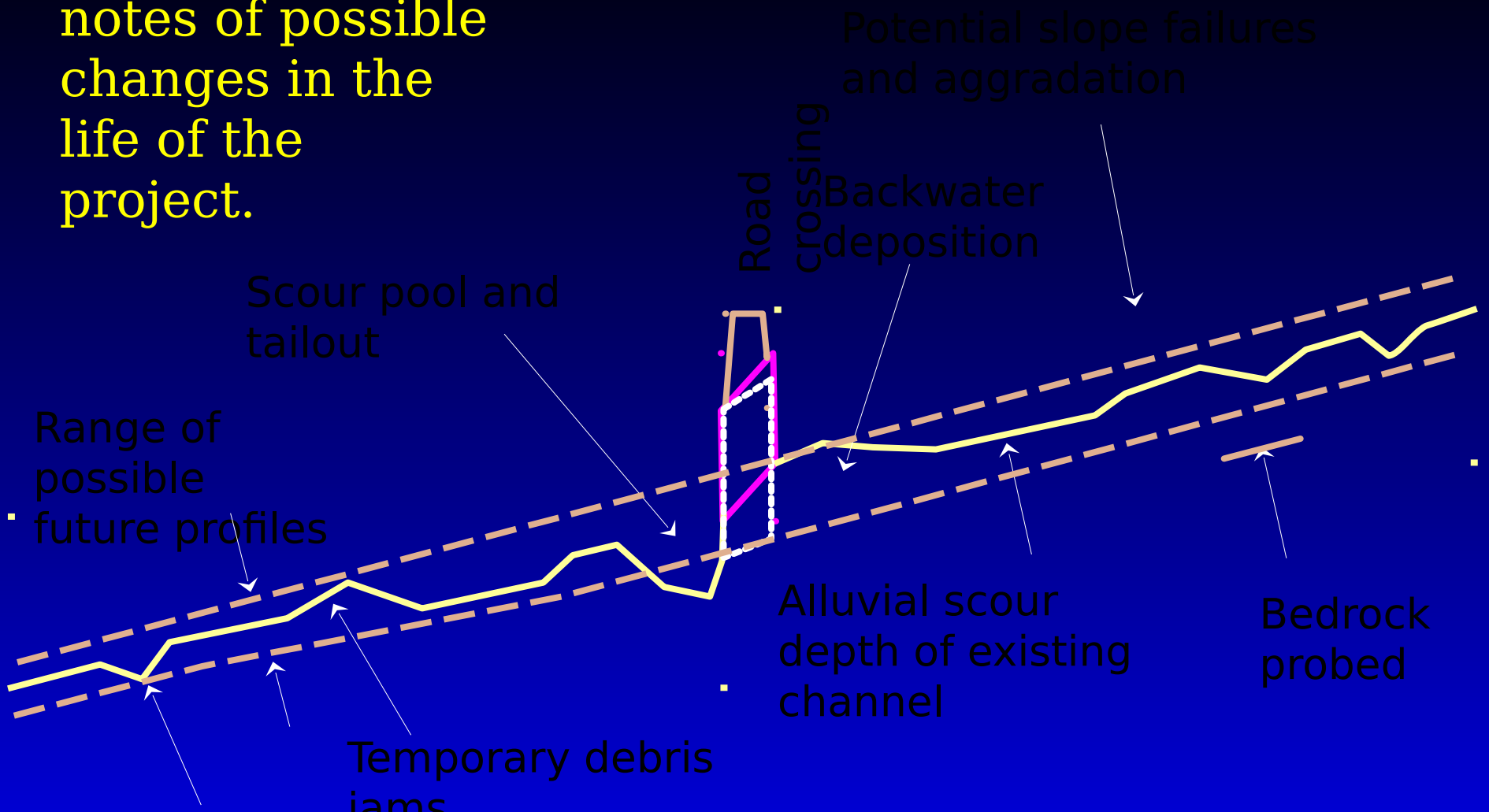
Culvert	Increase in Connectedness	Percent of Best
3	1301.12	100
2	813.41	62.5
4	194.60	15.0
6	141.15	10.8
5	117.24	9.0
1	65.25	5.0



Important Considerations for Culvert Replacement/Upgrades

- Stream channel adjustments and structure stability
- Upstream head cutting
- Loss or degradation of upstream wetlands
- Loss of flood control in developed watersheds

Long profile with notes of possible changes in the life of the project.

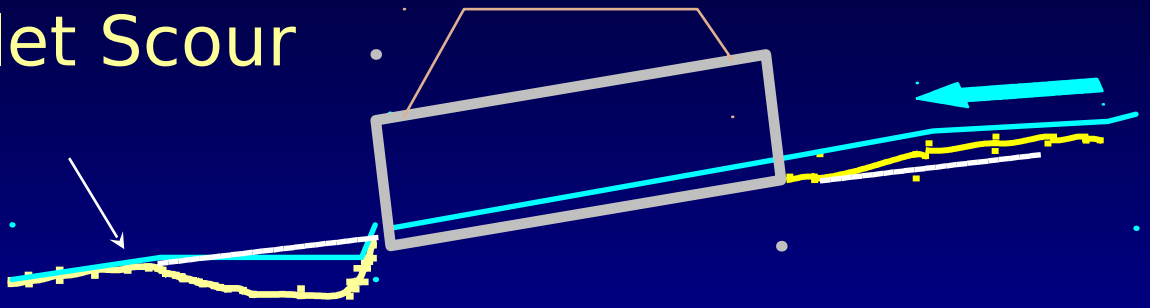


Kozmo Bates,

Scour Pool vs. Incised Channel

Outlet Scour

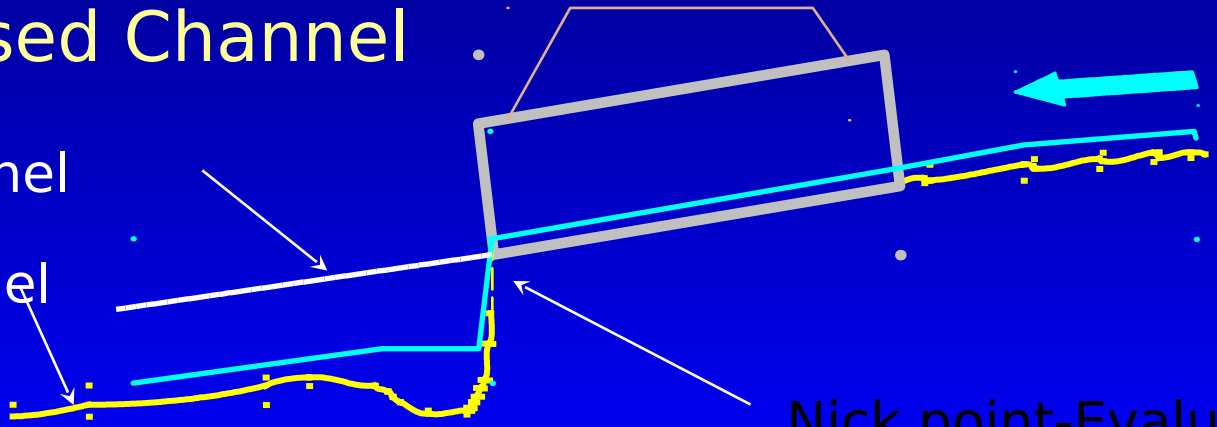
Original Channel Grade



Incised Channel

Original Channel Grade

Incised Channel Grade



Nick point-Evaluate losses

Kozmo Bates,

Headcut issues
Bed material

Wynoochee trib - 1983

Culvert replaced

Kozmo Bates,

Discussion Points

- Where should standards be applied?
- Can the standards be disaggregated?
- How/when should standards be applied to culvert replacements?
- Embedment depth
- Openness
- What technical design guidelines are needed?

Commonwealth of Massachusetts

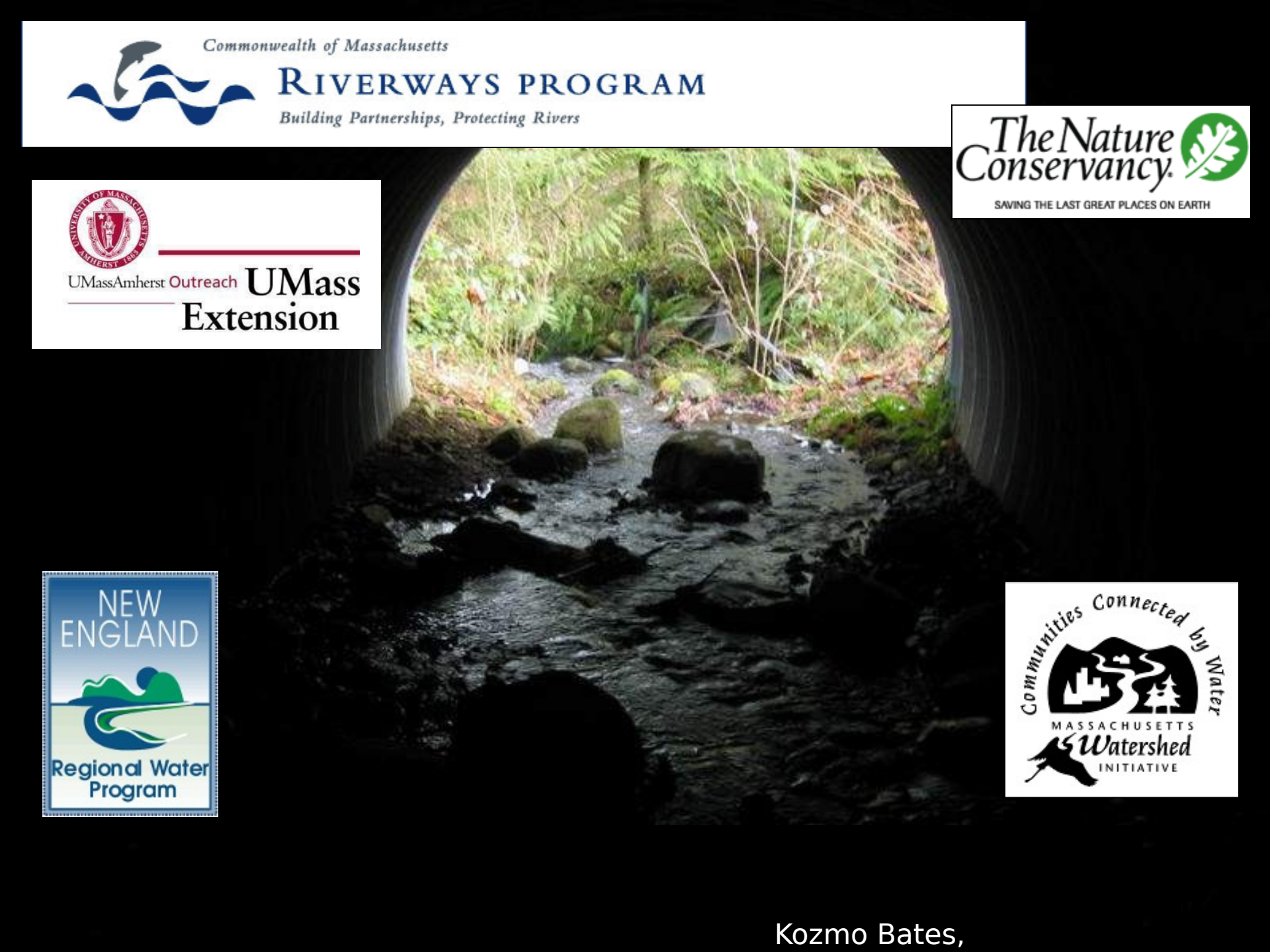
RIVERWAYS PROGRAM

Building Partnerships, Protecting Rivers

The Nature Conservancy

SAVING THE LAST GREAT PLACES ON EARTH

UMassAmherst Outreach UMass Extension



NEW ENGLAND Regional Water Program

Communities Connected by Water

MASSACHUSETTS Watershed INITIATIVE

Kozmo Bates,